Single-Cut Single-Screw Capitate-Shortening Osteotomy for Kienbock's Disease

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Abstract

Background Kienbock's disease, in spite of an uncertain natural history, is known to cause lunate compromise, leading to central column collapse, carpal instability, and degenerative arthritis of the wrist. Joint leveling procedures are performed in the early stages of Kienbock's disease to "unload" the lunate. Capitate shortening is the preferred procedure in Kienbock's patients with positive ulnar variance.

Description of Technique We describe the rationale and a simplified technique of capitate shortening in early Kienbock's disease. This is a single-cut osteotomy with single-screw stabilization.

Patients and Methods We have performed this technique in three cases. We present a case of a 26-year-old male who presented with a 1-year history of pain in his right wrist. Radiology performed demonstrated lunate sclerosis. Diagnostic arthroscopy revealed healthy articular surfaces. Single osteotomy capitate shortening was performed with an oscillating saw and fixed with a single cannulated compression screw. A shortening of 1.5mm was obtained with this technique.

Results At 1- to 2-year follow-up, all three patients had considerable pain relief but did not have a complete resolution of pain. There was a significant improvement in function and grip strength. There have been no cases with infection, nonunion, avascular necrosis or a need for a salvage procedure.

Conclusion The simplified technique of capitate shortening is easy to perform, less traumatic to the capitate vascularity, and leads to good short-term functional results.

Keywords
► Kienbock's disease
► capitate shortening
► joint leveling
► capitate vascularity
► capitate osteotomy

Just as the etiology of Kienbock's disease has remained controversial, so has the optimal treatment. Müller and Kienbock described the disease as one of overactivity from workplace activities, leading to "occupational lunatolmala-cia."[1,2] The etiology is thought to be multifactorial, with both biological and mechanical triggers.[3,4] Although the natural history is unclear, lunate compromise and fragmentation is known to cause central column collapse and proximal row instability. The late sequelais degeneration of the articular surfaces of the joint.[5]

There are three classification systems that define the osseous, chondral, and vascular components of the disease, which were described by Lichtman, Bain, and Schmitt, respectively.[5–9] Lichtman and Bain developed a classification

system and algorithm that incorporates all these factors when assessing and planning surgical management. The aim of surgical treatment is to bypass or excise "nonfunctional articular surfaces," thereby reducing pain and maintaining functional wrist movement.[6,10]

The concept of an unloading procedure is a well-recognized surgical treatment.[10] This procedure unloads the radiolunate articulation and also provides indirect revascularization due to regional hyperemia.[11] Several techniques have been described for capitate-shortening osteotomy. Some of these techniques are technically challenging, risk violating the blood supply to the capitate, and not easily reproducible. We will review the osseous and vascular anatomy associated with capitate shortening with the aim to optimize the accuracy, safety, and reproducibility of the technique.

Anatomy

Osseous

The capitate is the largest of the carpal bones. It articulates proximally with the lunate and scaphoid and distally with the base of the third metacarpal and, variably, fourth metacarpal.

The capitate has three parts; the head, neck, and body.[12] The head is the proximal articular aspect that has no ligamentous attachments.[12,13] Distal to the head is a narrow neck covered in the periosteum. The body is distal to the neck. The dorsal and volar aspects of the body have ligamentous attachments.[12,14–16] The volar aspect may have part of the adductor pollicis muscle insertion.[14] The hamate articulates with a flat but elongated facet on the ulnar aspect of the capitate.[14] The articular surfaces of these two joints are interrupted by the attachment sites for the deep trapezoid–capitate and capitate–hamate (CH) ligaments.[12]

The proximal capitate articulation has been classified into three types: flat, spherical, and V-shaped. The flat capitate is associated with a single distal lunate facet type I lunate. The spherical type was associated with a concave articulation formed by the scaphoid and lunate articulations, with an indistinct border between the scaphoid and lunate facets.

The "V"-shaped capitate is associated with the presence of a type II lunate, with a large hamate facet, hamate ridge, capitate ridge, and a fourth carpometacarpal facet on the distal capitate).[17] It is known that Kienbock's disease is more common if there is a type I lunate, which may be associated with a flatter proximal capitate articular surface. Capitate shortening is designed to unload the compromised lunate.[18–20]

Vascular Supply

The vascularity of the lunate is known to be important in Kienbock's disease. We expect the vascularity of capitate to be important for the risk of postoperative nonunion and/or avascular necrosis (AVN). Most research has been directed to the arterial supply.[21] Crock did some pioneering work on the venous drainage of the lunate.[22] We have been able to apply this to the etiological concepts of Kienbock's disease.[23,24]

Arterial

An anatomical study by Vander Grend et al[21] reported that the palmar blood supply was predominant. The palmar carpal branch provides vessels at the palmar ulnar border of the capitate neck. In addition, another large consistent branch from the deep palmar arch enters the palmar aspect of the distal capitate. Dorsally, the branches enter the capitate at the midwaist portion. There are no external vessels that enter the capitate head. Vander Grendet al reported that the capitate intraosseous blood supply has three types. In type 1, the arterial supply was exclusively from the palmar vessels. In type 2, both the palmar and dorsal arteries supplied the waist and distal capitate, but the head was predominantly supplied by the palmar vessels. In type 3, the proximal pole is equally supplied by the palmar and dorsal vessels.

The intraosseous arterial blood supply assessed by Kadar et al[25] using micro-CT reported the large arterial supply entering the capitate from the radial aspect of the neck.

Venous

Crock studied the arterial and venous systems and identified a subarticular venous plexus and a large single venous channel draining at the articular margin into a large single vascular channel (►Fig. 1).[22] Crock stated that a compromise to this venous plexus, through biological or mechanical factors, leading to venous stasis or venous hypertension, may play a part in the pathogenesis of AVN.[22] We consider that it is also important to avoid compromise of this large vein during osteotomy for Kienbock's disease.

Biomechanics of Capitate Shortening

Werber et al[26] described that a capitate shortening of 1.8 to 2 mm decreased the radiolunate pressure by 49to 56% and that the load was redistributed to the radial and ulnar columns.[27,28] Viola et al[29] reported a 25% decrease after 2.9-mm capitate shortening. Horii et al reported that a 4-mm capitate shortening with CH fusion decreased the radiolunate pressure by 66%.[30]

Fixation Options

Various authors have described different techniques to stabilize the osteotomy, including plates, Kirschner (K) wires, staples, and screws (►Fig. 2).[31–34]

Capitate Shortening

Almquist[19] recommended capitate shortening for Kienbock's disease in ulnar positive wrists. Various techniques have been reported and are presented in ►Table 1. A summary of these results is that there have been 89 cases reported in the literature. The ranges of motion are similar to the preoperative values. However, the mean grip strength improved from 47 to 58% to 63 to 80% of the contralateral wrist. The mean visual analog scale score improved from a score of 6.0 to 8.2 to a score of 1.7 to 3.3. All cases united in 6 to 8 weeks. There was one case with irritation from the K-wire. The concepts of
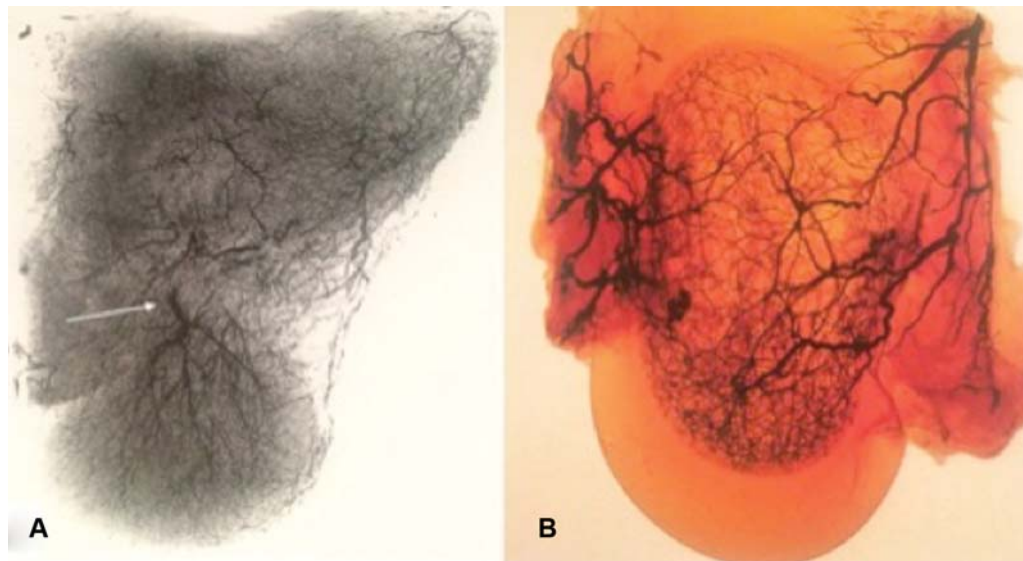
Fig. 1 Capitate vascularity. (**A**) The venous anatomy of the capitate. Note the single large vein draining the proximal capitate (white arrow). (**B**) The intraosseous arterial supply. (Reproduced with permission of Crock[22].)

Fig. 2 Different methods of fixation for capitate-shortening osteotomy.

Table 1 Types of capitate osteotomy

Author	Procedure
Waitayawinyu et al[33]	Capitate shortening with VBG to the lunate
Moritomoet al[18]	Capitate shortening in a reverse L shape
Citlak et al[31]	
Singer et al[32]	
Almquist[19]	Capitate shortening
Gay et al[34]	
Viola et al[29]	Capitate shortening with capitohamate fusion
Graner et al[35]	Lunate excision, capitate osteotomy with interposition bone graft.

Abbreviation: VBG, vascularized bone grafting.

partial capitate osteotomy and CH fusion were not obviously superior to a capitate osteotomy. However, patients with a lower Lichtman grade did have better outcomes.[32–35]

Single-Cut Single-Screw Capitate-Shortening Osteotomy

Based on the aforementioned anatomical and biomechanical factors, we propose a simplified technique of capitate osteotomy. We performed single-cut capitate osteotomy in three cases.

Indication for Capitate Shortening

The ideal scenario for capitate shortening is a patient who has a lunate that is intact (Lichtman and Bain grade B1) that should be protected. The wrist should have a neutral or positive ulnar variance.

Rationale for Single-Cut Osteotomy

The publication by Werber et al[26] has clearly demonstrated that the capitate shortening is very effective in reducing the radiolunate load. Shortening of 2mm, however, can result in a capitate that is not in contact with the lunate. The effect of this is to increase the load on the scaphotrapeziotrapezoid (STT) and triquetrohamate articulations. We believe that a 2-mm shortening is a lot for the midcarpal joint and likely to lead to a change in the mechanics more than is required. We believe that an osteotomy the width of the saw blade (~1 mm) is adequate to unload the joint and reduce the excessive loading on the ulnar and radial columns.

Rationale for the Site of Osteotomy

Review of the capitate arterial[21,36] and venous[22] supply demonstrates that the proximal capitate head has a retrograde vascular supply, including vessels within the volar capsule. Placement of the osteotomy at the STT joint line position will preserve the volar capsular vessels.

Rationale for Retrograde Fixation

Antegrade fixation of the capitate involves hyperflexing the wrist and introducing the screw through the articular surface. Hyperflexion of the wrist places undue pressure on the fragile lunate and could cause it to fragment. The retrograde method can be performed without flexing or violating the joint.

Rationale for Single Screw

When performing a capitate osteotomy, there is a concern about the risk of nonunion or AVN. However, there have been no nonunions or AVN in almost 100 cases of capitate shortening published in the world literature. Therefore, if we preserve the soft tissue envelope, we expect that the osteotomy will heal with the stability of a well-placed single screw.

Surgical Technique: "Retrograde" Single-Cut Single-Screw Capitate Osteotomy

A 26-year old male with right wrist pain for 1 year presented to our clinic. He had midcarpal tenderness, flexion of 60 degrees, extension of 45 degrees, radial deviation of 30 degrees, ulnar deviation of 30 degrees. Grip strength was 28 kg bilaterally. Imaging demonstrated neutral ulnar variance and lunate sclerosis with coronal fracture without carpal collapse (►Figs. 3 and 4).

The treatment options and prognosis were considered and discussed with the patient. At wrist arthroscopy, the radiocarpal synovitis was debrided. The radiocarpal and midcarpal joint surfaces were pristine. The wrist was graded as B1 using the Lichtmanand Bain classification. It was decided to preserve and unload the lunate and perform a capitate shortening.

At wrist arthroscopy, the articular cartilage was assessed using the Bain and Begg classification.[5] Any radiocarpal synovitis was debrided.
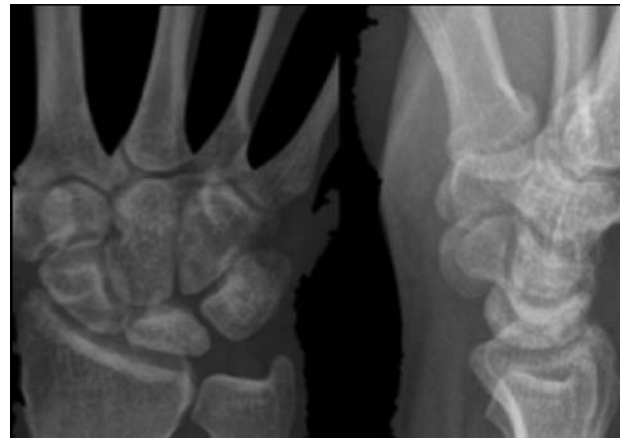

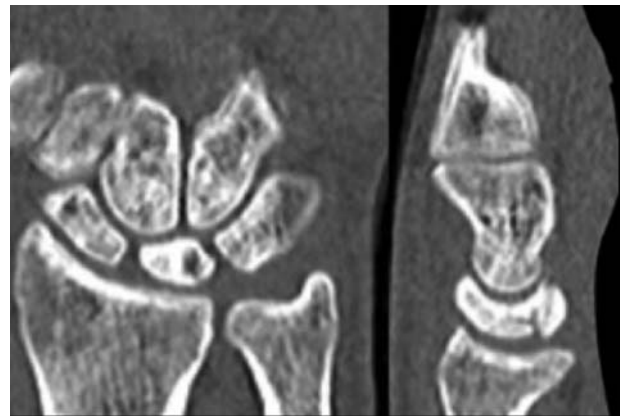Fig. 3 Preoperative radiographs showing Kienbock's disease with lunate sclerosis.

Fig. 4 Computed tomography images showing lunate sclerosis and a coronal fracture without carpal collapse.

Surgical Technique: "Retrograde" Single-Cut Single-Screw Capitate Osteotomy

We reviewed the plain radiographs to determine the correct alignment of the osteotomy. Our aim is to make the osteotomy parallel to the capitolunate articulation. This usually means that the osteotomy is slightly oblique (►Fig. 5).

The capitate is exposed through a dorsal approach. The extensor retinaculum does not need to be divided, as the capitate is distal to it. We predrill the osteotomy so that we try not to advance the K-wire into the unstable proximal capitate.

A small area of the third metacarpal base is removed with an osteotome to ensure the correct line of entry of the wire. A threaded guidewire is then passed down the capitate. On the anteroposterior plane, it is perpendicular to the proximal capitate joint surface. On the lateral projection, the wire is placed parallel to the dorsal cortex of the capitate. A cannulated drill is advanced over the wire and into the head of the capitate (►Fig. 6). We then remove the drill and the wire.

With a 6-mm-wide fine-tooth oscillating saw, a transverse capitate osteotomy is made distal to the midwaist (middle one-third) at the level of the STT joint (►Fig. 7).

Fig. 5 The osteotomy is designed relative to the axis of the lunocapitate joint, at the level of the STT joint. STT, scaphotrapeziotrapezoid.
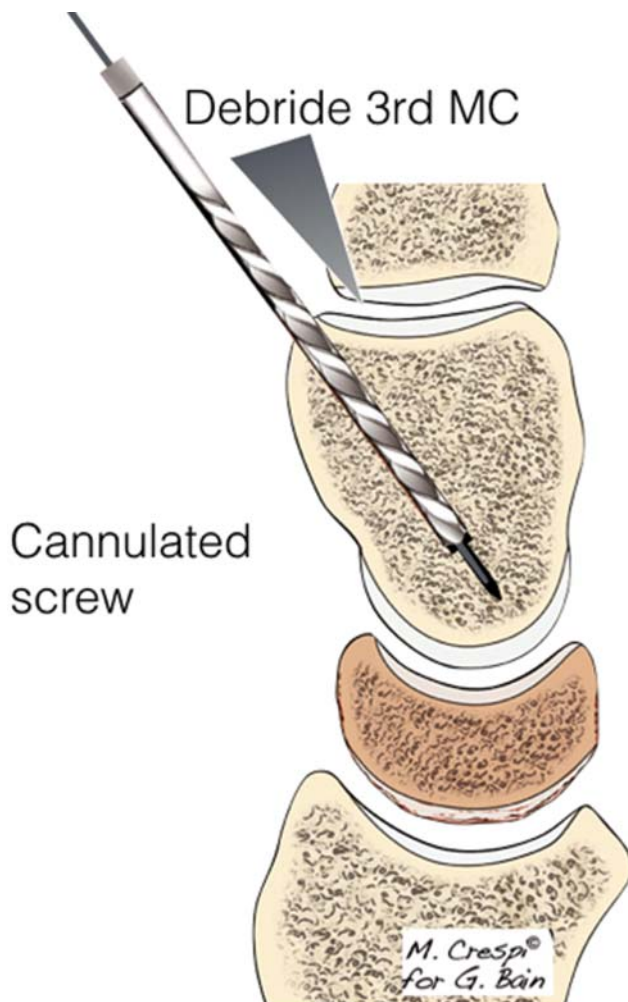

Fig. 6 A small area of the third MC base is removed with an osteotome to ensure the correct line of entry of the wire. A threaded guidewire is then passed down the capitate. On the lateral projection, the wire is placed parallel to the dorsal cortex of the capitate. A cannulated drill is advanced over the wire and into the head of the capitate. MC, metacarpal.
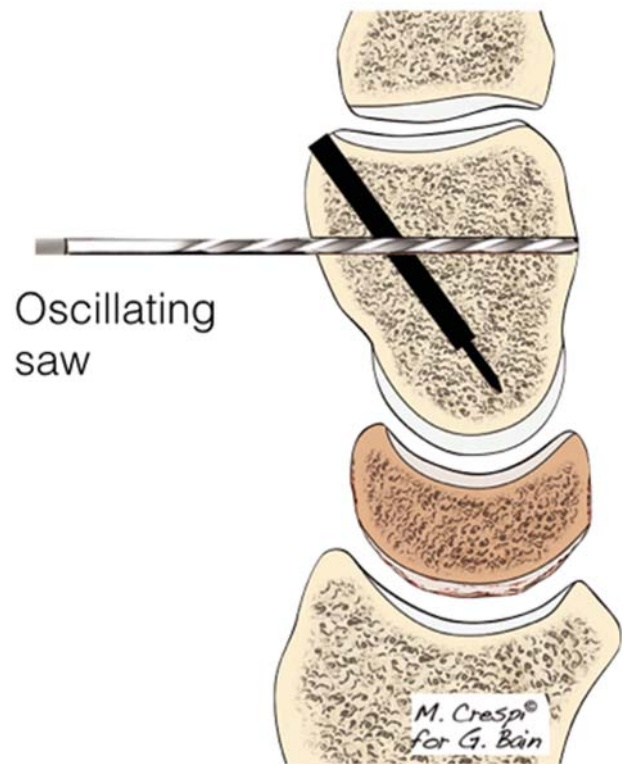
Fig. 7 With a 6-mm-wide fine-tooth oscillating saw, a transverse capitate osteotomy is made distal to the midwaist (middle one-third), at the level of the scaphotrapeziotrapezoid joint.

The osteotomy is not opened to preserve the soft tissue envelope. A sharp (5-mm) osteotome can be used to complete the osteotomy if necessary.

The K-wire is again inserted and then a single cannulated compression screw (2.2 mm) is advanced over the wire to compress the osteotomy (Medartis, Switzerland) (►**Fig. 8**). The position is confirmed to be satisfactory with fluoroscopy. Capsule and skin are sutured in layers.

The osteotomy is inherently stable following fixation; therefore, the wrist is only immobilized with a volar splint for 2 weeks. The patient can then commence gentle range-of-motion exercises. The patient can resume normal activity after 2 months. Radiographs at 6 months in our patient confirmed union with capitate shortening of 1.5 mm (►**Fig. 9**).

Results

All our three cases of capitate osteotomy have united. In line with previous publications, the patients did have some considerable pain relief but did not have a complete resolution of pain. There was an improvement in function and grip strength. There have been no cases with an infection, non-union, AVN, or need for a salvage procedure.

Discussion

Panagis et al[22] reported that the intraosseous vascularity of the capitate developed from both the palmar and dorsal aspects. Dorsally, two to four medium-sized vessels enter the
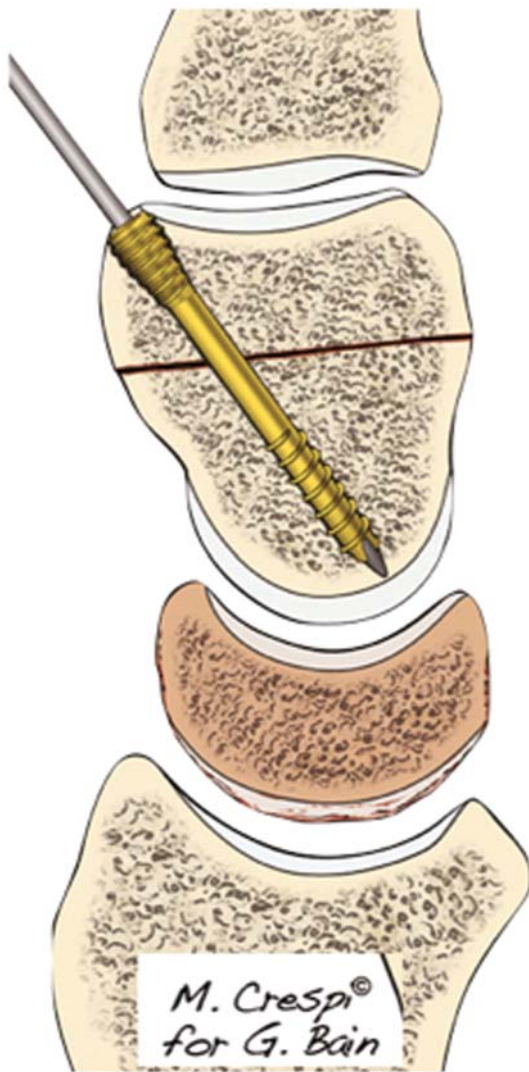
Fig. 8 The K-wire is again inserted and then a single cannulated compression screw (2.2 mm) is advanced over the wire to compress the osteotomy.

distal two-thirds of the concavity of that surface. The vessels course palmarly, proximally, and slightly ulnarly, supplying the capitate body and head in 67% of the cases. Rarely, some vessels entered proximally in the neck. Palmarly, one to three medium-sized vessels enter slightly more proximally than the dorsal blood vessels but within the distal half of capitate. In the study by Panagiset al, however, the dorsal vessels predominated in most specimens. In 30% of specimens, there was anastomosis between the dorsal and volar networks.

The capitate proximal pole is supplied in a retrograde manner similar to the scaphoid. Cadaver studies have demonstrated vascular penetrations through the volar capsule at the articular margin.[37] Hence, considering the unique vascularity, the osteotomy should be performed with precaution in theleast traumatic way as possible to the bone as well as volar carpal ligament to avoid the risk of AVN. It is recommended that the osteotomy is best performed no more proximal than the capitate waist. The technique reported in this article uses only a single cut, thereby decreasing the risk of compromising the capitate. We believe that 1mm is enough to effectively unload the lunocapitate joint. Shortening more than this risks overloading the remaining midcarpal joints and the development of osteoarthritis, although this has not yet been proven.

There are few clinical studies on capitate shortening. Almquist reported a clinical series of 83% revascularization and healing of the lunate after capitate shortening with CH arthrodesis.[37]

Overall, isolated capitate shortening, as described in this article, is easiest with a single cut and fixation with a single screw, which is adequate to stabilize the shortened capitate. This procedure has the advantage of shorter rehabilitation, and it can be combined with vascularization of the lunate if deemed necessary. Limitation of this procedure is that it increases the loads on the STT and TH joints, which may lead to degeneration later.[30]

Fig. 9 Follow-up radiographs: united capitate osteotomy with no signs of avascular necrosis. No further collapse in the lunate was noted.

Note
The study was performed at Flinders University, Adelaide, Australia.

Conflict of Interest
None declared.

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