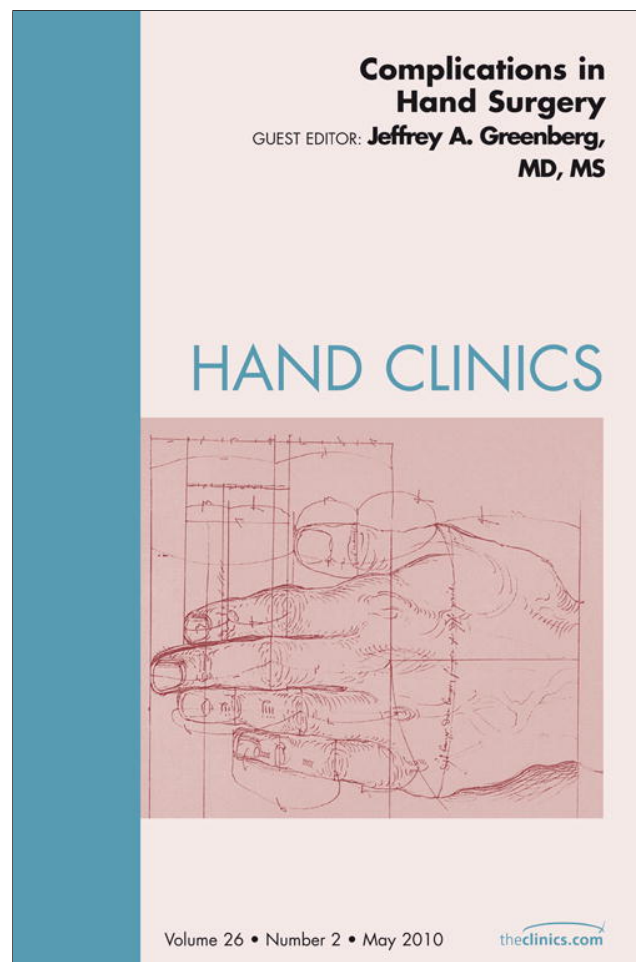


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Complications of Limited and Total Wrist Arthrodesis

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KEYWORDS

- Total wrist arthrodesis • Partial wrist arthrodesis
- Complications • Four-corner fusion

Partial and total wrist arthrodeses have become common procedures for treating degenerative diseases arising from numerous conditions, including posttraumatic arthrosis, intercalated segment instability, inflammatory arthropathy, and carpal osteonecrosis. Wrist arthrodesis also has a role in the treatment of midcarpal instability, severe spastic deformity, paralysis of the hand, and bone loss from tumor or trauma. The first report of total wrist arthrodesis dates back to 1910 in treatment of tuberculosis,¹ and Thornton² reported on the first limited wrist fusion in 1924 when he successfully fused the scaphoid, lunate, capitate, and hamate.

The goals of limited wrist arthrodesis are similar to those of total wrist arthrodesis in providing pain relief and improved function by fusing across arthritic or unstable joints, with the added benefit of motion preservation. Biomechanical studies have determined that between 30% and 50% of sagittal motion at the wrist occurs through the midcarpal joint, with the remainder through the radiocarpal joint.^{3,4} Sparing of either the midcarpal or the radiocarpal articulations avoids complete loss of wrist motion, and a compensatory increase in motion at the unfused joint has been shown for up to 1 year postoperatively.^{5,6} Despite the success, wrist arthrodeses are not without risk, and overall minor and major complication rates of up to 51% to 68% have been reported in large series.^{7,8} Awareness of the complications associated with wrist arthrodesis and how best to

avoid them is essential for the treating physician to appropriately counsel patients on different arthrodesis options and to inform them on what to expect from the procedure.

Although many different versions of wrist arthrodesis have been described, this article focuses on the complications associated with total wrist fusion and the more common limited arthrodeses, including scaphoid excision and four-corner fusion, scaphotrapeziotrapezoid (STT) fusion, and isolated radiocarpal fusion.

NONUNION

Nonunion after wrist arthrodesis is directly related to several factors. The first is the articulations of the individual bones within the carpus. The size of the bones and the small surface area of the joints would appear set up for nonunion, especially in comparison with the large torques that are applied to the carpal bones by the intrinsic and extrinsic ligaments of the wrist. This has been corroborated by the poor fusion rates in attempts at arthrodesis of single articulations within the carpus, including the scapholunate^{9,10} and lunotriquetral^{10,11} joints (**Fig. 1**). It is for this reason that adjacent carpal bones are now included in limited fusions, such as STT fusion and four-corner fusion, which show improved union rates without established deleterious effects (**Fig. 2**).¹² The second important factor for achieving union is the stability of fixation. Total wrist arthrodesis evolved over

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Fig. 1. Anteroposterior radiograph showing failed arthrodesis of the scapholunate joint with a broken compression screw.

time from uninstrumented fusion with structural corticocancellous graft,¹³ to transarticular pin fixation,¹⁴ to intramedullary fixation,¹⁵ and most recently to dorsal compression plating,^{8,10,16} which has achieved nonunion rates of 2% to 4%^{8,16} as opposed to rates as high as 19%¹⁷ by



Fig. 2. Anteroposterior radiograph showing a successful scaphoid excision and four-corner fusion.

using older fixation techniques. Hastings and colleagues,⁸ in their series of 90 wrists, noted a nonunion rate of 2% with dorsal plating compared with 18% with other techniques. Although limited wrist arthrodesis has traditionally been performed with pin fixation, the use of circular plates with the theoretical advantage of increased construct rigidity gained popularity in the past, especially for scaphoid excision and four-corner fusion. However, although comprehensive literature reviews covering decades of treatment have reported nonunion rates between 4% and 8% in four-corner fusions with pin fixation,^{10,18,19} the union results with circular plate fixation have been much more variable, with nonunion rates as high as 10% to 62.5%.^{20–23} The initial enthusiasm for these has now waned.

Several other factors that affect union after wrist arthrodesis must be considered irrespective of the fixation type or site of fusion. Preparation of the fusion surfaces is critical and must include meticulous removal of all articular cartilages (**Fig. 3A**) and direct apposition of the surfaces, with compression when possible at the time of application of fixation. Compression specifically improves stability. The use and type of bone graft used are also potential factors. Although there is no good comparative data specifically addressing bone graft in this setting, it has been our experience that the excised carpal bones are often sclerotic with minimal good-quality cancellous bone, and thus we advocate the use of distal radius, iliac crest, or other source of fresh cancellous autograft packed into the fusion surfaces (**Fig. 3B**). Patient-related factors, such as avoiding tobacco use and compliance with immobilization and activity restriction until union are critical, and their importance must be communicated to the patient.

In comparison to total wrist arthrodesis and four-corner fusion, the nonunion rates of other common wrist arthrodeses seem higher. Series of STT fusions have had nonunion rates ranging from 0% to 29%,^{24–28} with a meta-analysis reporting 14% nonunion.¹⁰ Watson and colleagues²⁵ reported a nonunion rate of 4% in their large series of 800 STT fusions, well below most other rates in the literature, and these authors emphasize generous preparation of the fusion bed by resecting more than just the articular surface to provide well-opposed edges, routine use of distal radius cancellous autograft, parallel pins to allow compression along the pin axis, and 3 weeks of long-arm immobilization including the thumb followed by short-arm immobilization. Nonunion rates are less frequently reported after radioscapulunate fusion and vary from 5% to 27%.^{29–31}

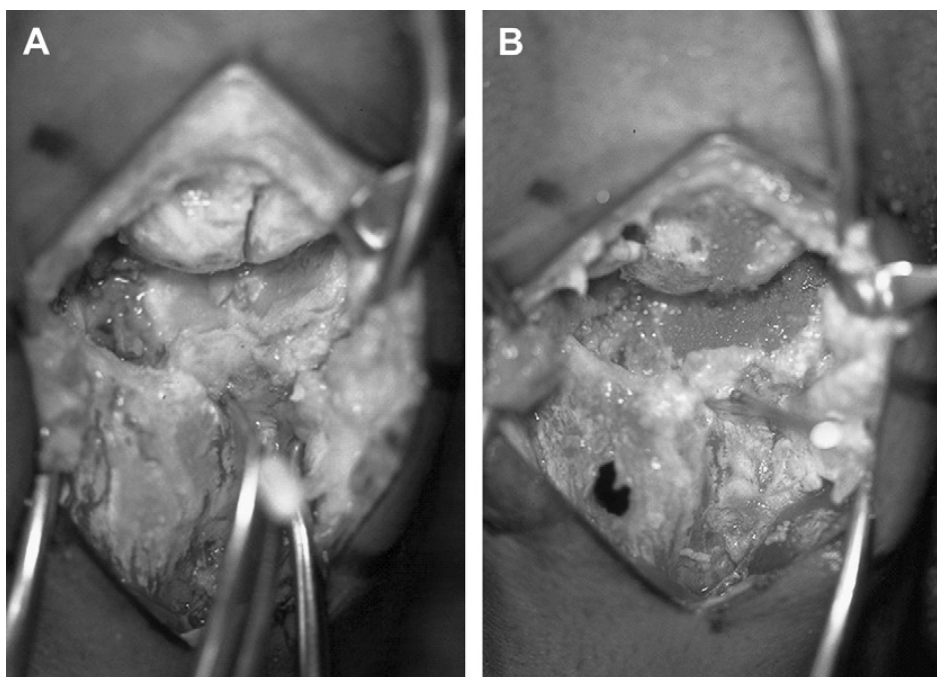


Fig. 3. The fusion surfaces after (A) removal of the articular cartilage and (B) placement of cancellous autograft during the preparation for scaphoid excision and four-corner fusion.

INFECTION AND WOUND COMPLICATIONS

Several aspects of wrist arthrodeses make these procedures prone to wound complications. The exposure often requires raising large soft-tissue flaps and the dorsal wrist skin, and subcutaneous tissue can be thin, especially in patients with inflammatory arthropathy who have been on oral steroid therapy. The extensive bony preparation required also predisposes patients to postoperative hematoma formation.

Overall wound complication rates associated with partial and total wrist fusions, including blistering, hematoma, and minor dehiscence, have been reported in 20% to 30% of cases.^{7,8,17} Most tend to resolve without reoperation, although complete wound breakdown requiring secondary skin grafting has been reported.³² Infection rates seem to be low, with a superficial infection rate of about 3% and a deep infection rate of 0.5%.^{7,8,17,19,33,34}

Several steps can be taken to reduce the likelihood of wound complications. Preoperatively, appropriately administered prophylactic antibiotics against typical skin pathogens are routinely used. Intraoperatively, full-thickness flaps down to retinaculum and meticulous hemostasis are especially important. Postoperatively, a compressive dressing and a temporary splint may help soft-tissue healing.

HARDWARE COMPLICATIONS

The thin nature of the skin and the subcutaneous tissue of the dorsal wrist that predisposes to

wound complications predisposes patients to symptomatic prominent hardware. Dorsal compression plating with a small fragment implant has resulted in symptomatic hardware in the form of either a painful prominence or a bursa in 35% to 65% of cases,^{32,35-37} frequently requiring implant removal (**Fig. 4**). Although there is no universally agreed upon standard, plate removal should not be attempted until 6 months and preferably 12 months after placement, with clear evidence of radiographic union.



Fig. 4. Lateral radiograph after total wrist arthrodesis showing pullout of the dorsal plate.

Removal of the implant is not without consequence, as fractures through previous screw holes in the radius³² and in the metacarpal^{7,8} requiring replating have been reported. Immobilization of the wrist and limited activity for 6 weeks after implant removal should be strongly considered.

Extensor tendon adhesions and synovitis are also not uncommon after total wrist arthrodesis, likely from a combination of irritation over a dorsal implant and postoperative scarring. The need for repeat operation for tenosynovectomy and tenolysis has been reported to be as high as 43%, with dorsal plate fixation in total wrist fusion.⁸ Intraoperatively, at the time of arthrodesis, all attempts should be made at interposing tissue between hardware and the extensor tendons. It is helpful to elevate the fourth dorsal compartment subperiosteally, maintaining the subsheath around the tendons for protection. If the joint capsule is insufficient to cover a small area of hardware, a transverse incision across the retinaculum can allow one half of the retinaculum to be placed between the plate and the tendons and the other half to be repaired to its normal position to prevent bowstringing. Early range of motion of the digits postoperatively and attention to this potential complication during physiotherapy is critical. The use of newer precontoured total wrist fusion plates that have a smaller dimension over the metacarpal than traditional small fragment implants have shown promising results in decreasing the rate of hardware-related complications.^{38,39}

Circular plate fixation for scaphoid excision and four-corner fusion carries a risk of dorsal impingement of the implant at the radiocarpal joint in wrist

extension (**Fig. 5A**). This is reported in up to 22% of cases by Vance and colleagues²² and 25% of cases by Shindle and colleagues.²³ The site of fixation must be adequately reamed such that the implant will sit flush with or even slightly buried below the dorsal articular surface (**Fig. 5B**). Maximal bone stock and length of the carpus must be preserved while preparing the fusion surfaces so that the plate's proximal edge does not end up too close to the radius. It is critical that the lunate be reduced into neutral or slight flexion to restore midcarpal alignment (**Fig. 6**). This not only optimizes biomechanics to provide wrist extension⁴⁰ but also maximizes the length of the carpus to provide more clearance for the implant.

NERVE COMPLICATIONS

Injury to the major peripheral nerves of the hand is an uncommon complication of wrist arthrodesis,⁷ as they are usually located away from the surgical site during a dorsal approach. Dorsal sensory branches of the radial and ulnar nerves, conversely, are more at risk during wrist arthrodesis from injury during the surgical dissection and the placement of percutaneous pins. Reported rates of either painful neuroma or decreased sensation in a sensory nerve distribution most commonly range between 2% and 5%,^{7,8,22,32,35,41,42} and it is not clearly established if the risk is higher with plate or percutaneous pin fixation.^{8,22} To help prevent these complications during open dorsal exposures, sensory branches should be kept in the flaps and protected from



Fig. 5. Lateral radiographs after scaphoid excision and four-corner fusion showing (A) an extended lunate and dorsal prominence of the plate leading to impingement and (B) a correctly positioned lunate and well-seated plate with no dorsal impingement.

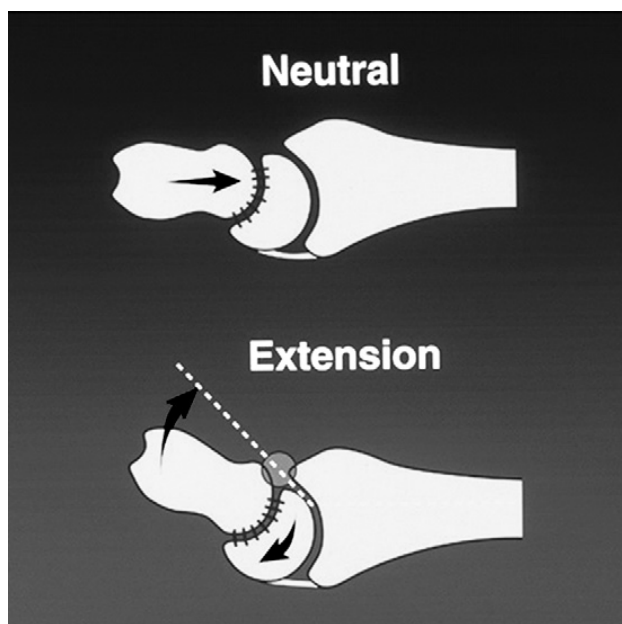


Fig. 6. Dorsal impingement secondary to an extended lunate compared with neutral alignment.

excessive retraction throughout the procedure. If pin fixation is going to be used outside the dorsal incision, we recommend wires be placed either percutaneously through a 16-gauge needle as a soft-tissue protector or under direct visualization through a small open incision. This is especially critical on the radial side of the wrist in the area of the dorsal sensory radial nerve branches.

Postoperative carpal tunnel syndrome is a well-recognized complication of total wrist arthrodesis. This complication is reported less frequently with

limited wrist arthrodesis. The incidence seems higher with dorsal plate fixation than with other means,⁸ with an overall rate of 10% to 25% after plate fixation. Approximately half of these cases require carpal tunnel release eventually.^{8,17,36} We routinely perform a carpal tunnel release with total wrist arthrodesis to avoid this complication.

Complex regional pain syndrome is a rare but devastating complication of wrist arthrodesis, with a reported incidence of approximately 2% to 3% in larger series.^{8,19,32} Rates are similar between total and limited wrist fusions. Avoidance of tight dressings; adequate pain control; and early recognition and treatment of dystrophic signs and symptoms with appropriate physiotherapy and agents such as calcium channel blockers, oral steroids, and neuroactive agents have roles in prevention and treatment. If early symptoms progress, consultation from a pain specialist is often warranted with a multidisciplinary approach to the condition.

ADJACENT ARTHRITIS

Degenerative disease in adjacent joints has been reported in the distal radioulnar joint (DRUJ) after total arthrodesis. Symptomatic DRUJ arthritis that required distal ulna resection in 3% of patients at a mean period of 1 year has been reported in one series.⁷ Adjacent arthritis is more common after limited wrist arthrodesis (**Fig. 7**), with radiocarpal and trapeziometacarpal arthritis reported in long-term series of STT fusions. At 5 years postoperatively, Fortin and Louis²⁶ found adjacent

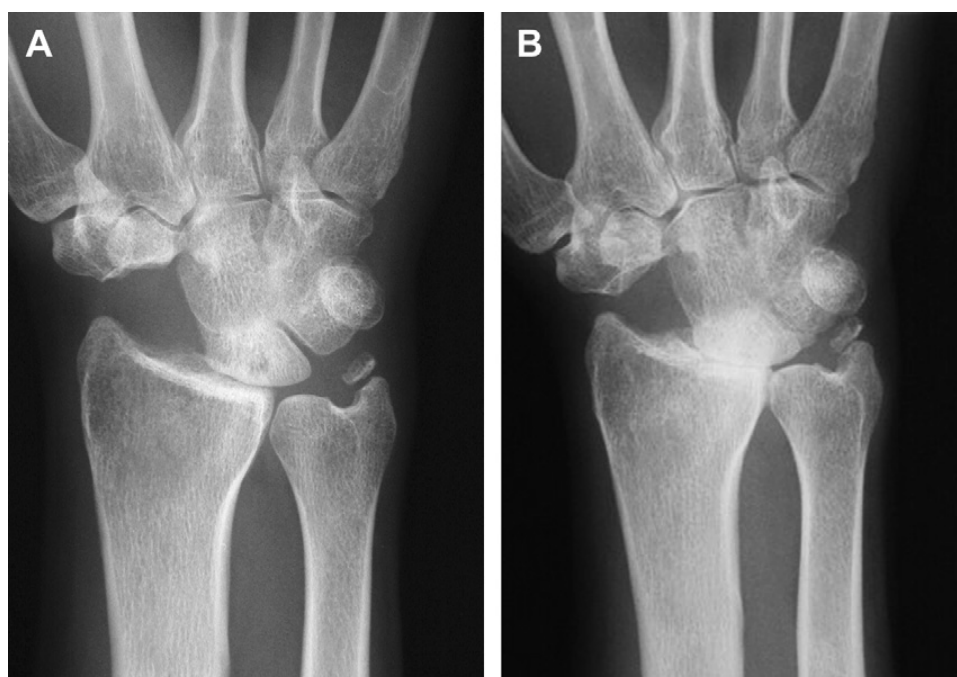


Fig. 7. Anteroposterior radiographs after scaphoid excision and four-corner fusion (A) at the time of radiographic arthrodesis and (B) 5 years postoperatively showing advanced adjacent arthritis of the radiolunate joint.

degenerative disease in 71% of their cohort, with inadequate reduction of the scaphoid being predictive for a poor outcome. Series by Minami and colleagues²⁴ and Kleinman⁴³ have reported incidences of 23% and 19%, respectively. Secondary midcarpal arthrosis after radioscapholunate arthrodesis occurs in approximately one-third of patients in long-term follow-up, and the rates were similar whether the procedure was done for posttraumatic arthrosis or inflammatory arthropathy.^{30,44,45} Patients must be carefully screened and selected, as preexisting adjacent joint arthrosis may preclude limited arthrodesis. In limited arthrodeses that preserve the radioscaphoid articulation, it is critical that the scaphoid be reduced into as anatomic a position as possible, given its complex shape.^{26,43} Conversely, the relatively uniform convexity of the lunate's articular surface with the radius likely explains the paucity of radiolunate arthrosis that occurs after scaphoid excision and four-corner fusion.

IMPACTION

Total wrist arthrodesis has been associated with ulnocarpal abutment, which manifests as ulnar wrist pain caused by forearm rotation activities of daily living or firm gripping or grasping.⁷ Patients whose fixation extends onto the second metacarpal instead of the third may be positioned in an additional ulnar deviation that may predispose to abutment. An incidence for this complication is difficult to estimate. Zachary and Stern⁷ reported one case in their series (with an overall incidence of 1%) that was treated with a distal ulna resection, and Trumble and colleagues⁴⁶ reported on a series of 3 cases, all of which had good results from excision of the pisiform or triquetrum. This complication, when recognized, is best treated with joint leveling procedures in ulnar positive patients, especially if they are young and the DRUJ is intact. Resection of either the distal ulna or the diseased portions of the carpus is recommended in older lower-demand patients with ulnar neutral or negative variance or an unsalvageable DRUJ.

IMPINGEMENT

Radial styloid impingement is a well-recognized complication of STT fusion. Rogers and Watson reported this complication in 33% of their original series of 93 patients, with 18% requiring a secondary radial styloidectomy. They recommended routine styloidectomy as an integral component of an STT fusion (Fig. 8).⁴⁷ Watson and Wollstein⁴⁸ later reported an improved secondary radial styloidectomy rate of 7.3%,



Fig. 8. Anteroposterior radiograph of a successfully fused STT arthrodesis with radial styloidectomy.

performed at 1.2 years postoperatively in their follow-up series of 800 STT fusions. They noted a higher incidence of radial styloid impingement in patients treated for scapholunate ligament injury than those treated for Kienbock disease. Because other preferred treatment options exist for scapholunate ligament injury and Kienbock disease, we believe that the principle indication for STT fusion is for isolated STT arthritis. We support Watson and Wollstein's recommendation of routine radial styloidectomy. Reduction of the extended scaphoid to a position of neutral or slight volar flexion within the scaphoid fossa is critically emphasized.⁴⁸ The irregular shape of the scaphoid coupled with its frequently extended position preoperatively serve as explanations for the higher rates of impingement in patients with the abnormal kinematics of scapholunate ligament injury.

The rates of dorsal impingement after scaphoid excision and four-corner fusion with traditional fixation techniques after comprehensive review are reported as 4%.¹⁹ Early reports of the rate of impingement with dorsal circular plating are variable but seem higher than with traditional methods. The most important technical aspect of this procedure to avoid impingement involves proper rotation and reduction of the lunate as discussed earlier (see Fig. 6).

PERSISTENT PAIN

Despite the theoretical benefit of eliminating pain via fusion of diseased articulations, wrist arthrodesis does have significant rates of persistent pain

associated with it, especially after activity and heavy work. The ability to draw conclusions from the literature regarding persistent pain is limited by the different ways in which investigators measure and describe impairment. For total wrist arthrodesis, Sauerbier and colleagues⁴⁹ found that 70% of patients had no pain at rest, but only 40% had no pain with work or heavy use. De Smet and Truyen's results were somewhat worse, reporting that 55% of patients were pain-free at rest and only 17% were pain-free with manual activity.⁵⁰ Zachary and Stern reported significant chronic pain in 8% of their series.⁷

Tomaino and colleagues⁵¹ and Wyrick and colleagues⁵² looked specifically at persistent pain after scaphoid excision and four-corner fusion and found more than 25% of patients with scaphoid excision and four-corner fusion to have either severe persistent pain or inadequate pain relief. Vance and colleagues²² reported moderate or severe pain in 53% of patients after plate fixation and 21% after pin fixation for four-corner fusion. More promising results have been shown by Cohen and Kozin⁴⁰ who showed that 21% of patients have long-term requirement for pain medicine, and Merrell and colleagues³³ who found a mean Visual Analog Scale pain score of 2.3 and an 88% return to manual labor. Few series of STT or limited radiocarpal fusions have reported on generalized persistent pain, with most focusing on the onset of radiographically proven adjacent arthritis, the results of which have already been discussed.

Although it is difficult to reach definitive conclusions regarding pain relief based on the existing data, it must be stressed that during the preoperative evaluation, all potential sites of arthrosis within the wrist and carpus must be closely assessed radiographically and by direct inspection, so that an inadequate or an inappropriate procedure does not fail early because of the development of early adjacent arthritis. As for generalized persistent pain, it is fair to warn patients, especially those who are higher-demand individuals, that although most series agree that patients improve from their preoperative condition, it is not uncommon to have persistent pain especially with activity. This is especially true in total wrist arthrodesis in higher-demand individuals.

SUMMARY

Total and partial wrist arthrodeses encompass various procedures to treat numerous conditions. It is this variability that mandates meticulous preoperative consideration of each patient's specific pathology and goals. Despite the high overall minor and major complication rates frequently reported with wrist arthrodesis, most

of these tend to be temporary and do not preclude a good outcome. A thorough understanding of the complications and the best practices to avoid them is critical for the surgeon in the preoperative, intraoperative, and postoperative management of candidates for total or limited wrist arthrodesis.

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