Carpal Instability: Evaluation and Treatment

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Abstract

Carpal instability is a common cause of wrist pain, motion loss, and disability. Diagnosis and treatment of carpal instability are dependent on a clear understanding of wrist anatomy and carpal kinematics, both normal and pathologic, as well as their relation to the current concepts regarding management. A brief review of anatomy and normal kinematics is presented, followed by a detailed discussion of specific instability patterns, including pathomechanics. A treatment algorithm is provided, detailing the authors' preferred treatment for the most common instability patterns.

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Carpal instability accounts for a significant percentage of all wrist injuries and can result in chronic pain, loss of motion, weakness, and degenerative arthritis if not diagnosed and treated appropriately. Unfortunately, selecting the optimal treatment is difficult and at times confusing.

The general attributes of carpal instability were first described by Linscheid et al[1] in 1972. Much new information on this entity has been accumulated since then. This article will summarize current concepts regarding the anatomy, injury mechanism, classification, and treatment of this common wrist disorder.

Anatomy

The carpus is a complex unit of eight bones arranged in two rows that articulate with the distal radius and triangular fibrocartilage complex (Fig. 1). The proximal row consists of the scaphoid, lunate, and triquetrum. The distal row contains the trapezium, trapezoid, capitate, and hamate. The pisiform is a sesamoid bone within the tendon of the flexor carpi ulnaris. Despite being considered a carpal bone, it does not play a significant role in carpal instability due to its confined location. The scaphoid, however, occupies an important position as the link between the proximal and distal rows. No muscles or tendons attach to the carpus; therefore, the stability of each individual carpal bone is dependent on bone surface anatomy and ligament attachments.

Two major groups of ligaments are present in the wrist: extrinsic ligaments, which are extracapsular and pass from the radius or metacarpals to the carpal bones, and intrinsic ligaments, which are intracapsular and originate from and insert on adjacent carpal bones (Fig. 2).[2,3]

The extrinsic system consists of dorsal and palmar components. The palmar system is composed of the radial collateral ligament, the palmar radiocarpal ligaments, and the ulnocarpal complex. The palmar radiocarpal ligaments are (1) the radioscaphocapitate ligament, which passes across the waist of the scaphoid and may be a factor in scaphoid waist fractures; (2) the radiolunate ligament, which passes from the radius to the triquetrum with an insertion on the lunate; and (3) the radioscapholunate ligament (ligament of Testut), which provides a check on scaphoid proximal pole motion and has also been described as a remnant of vascular ingrowth to the carpus during the embryologic state. The ulnocarpal complex consists of the ulnolunate ligament, the triangular fibrocartilage, the ulnar collateral ligament, and the dorsal and palmar radioulnar ligaments. The dorsal extrinsic ligaments are three ligaments that originate on the dorsal rim of the radius and insert distally: (1) the radiotriquetral ligament, which is an important stabilizer to prevent volar intercalated segment instability (VISI); (2) the radiolunate ligament; and (3) the dorsal radioscaphoid ligament.

The intrinsic ligaments are thicker and stronger volarly than dorsally and are grouped according to their length. The short intrinsic ligaments connect the bones of the distal carpal row. These ligaments seldom fail as a result of injury. The intermediate intrinsic ligaments include the scapholunate ligament, the lunatotriquetral ligament, and the ligaments connecting the scaphotrapezial joint. Two long

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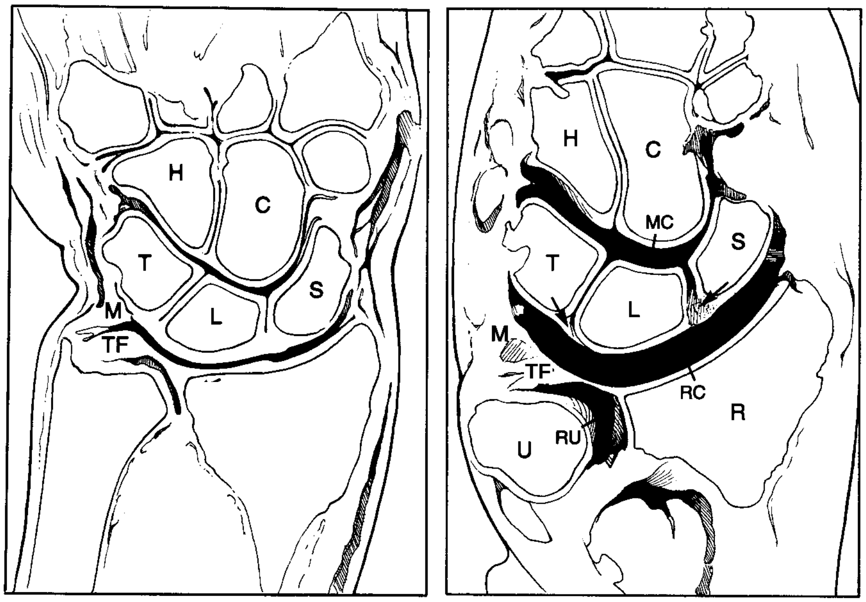


Fig. 1 **Left,** Sagittal section through the wrist. C = capitate; H = hamate; L = lunate; M = meniscus homologue; S = scaphoid; T = triquetrum; TF = triangular fibrocartilage. **Right,** Sagittal section through wrist with distraction. MC = midcarpal joint; R = radius; RC = radiocarpal joint; RU = distal radioulnar joint; U = ulna. Arrows indicate scapholunate and lunatotriquetral ligaments.

intrinsic ligaments are present. The dorsal intrinsic intercarpal ligament passes from the scaphoid to the capitate and the triquetrum. The long palmar intrinsic ligament is referred to as the V, or deltoid, ligament. It originates from the scaphoid and triquetrum and inserts on the capitate in a V-shaped pattern. This ligament provides stability to the midcarpal joint.

Mayfield and associates[4] have measured the stress-strain behavior of these ligaments and the load at failure. Their data indicate that the interosseous ligaments of the proximal row are stronger than the volar capsular ligaments and play an important role in carpal stability.

Kinematics

The carpal articulations allow motion in two planes: flexion-extension and radial-ulnar deviation. The average total arc of wrist flexion-extension is 121 degrees, with a range of 84 to 169 degrees.[5] Of this total, approximately half of the motion occurs at the radiocarpal joint and half occurs at the midcarpal joint. Radial ulnar deviation is also distributed across the two joints, with 60% occurring at the midcarpal joint and 40% at the radiocarpal joint.[6] The center of rotation of the wrist about which these

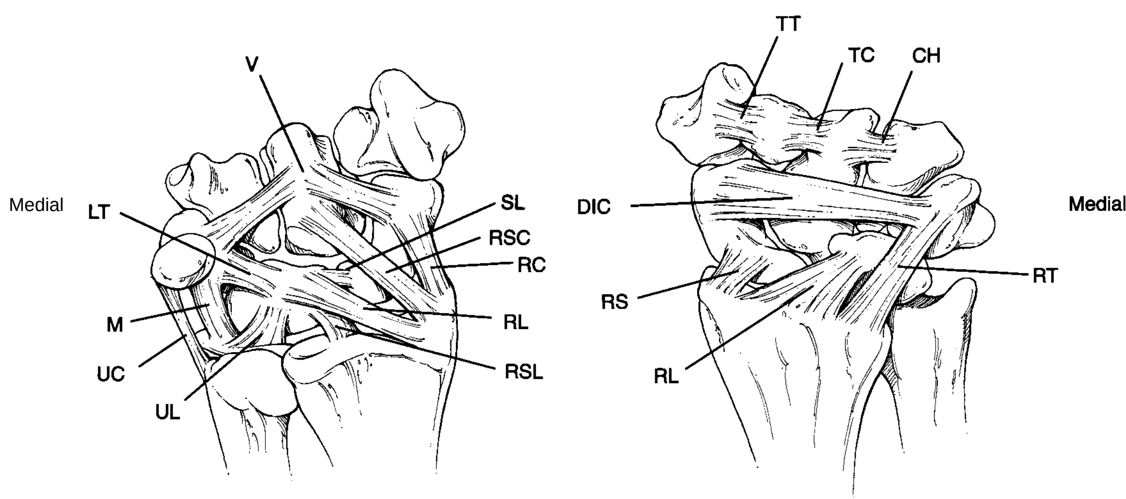


Fig. 2 Wrist ligaments (right hand). **Left,** Palmar ligaments. Extrinsic: M = meniscus homologue; RC = radial collateral; RL = radiolunate; RSC = radioscaphocapitate; RSL = radioscapholunate; UC = ulnar collateral; UL = ulnolunate. Intrinsic: LT = lunatotriquetral; SL = scapholunate; V = deltoid. **Right,** Dorsal ligaments. Extrinsic: RL = radiolunate; RS = radioscaphoid; RT = radiotriquetral. Intrinsic: CH = capitohamate; DIC = dorsal intercarpal; TC = trapeziocapitate; TT = trapeziotrapezoid.

motions occur lies within the head of the capitate.

The midcarpal and radiocarpal joints not only contribute different amounts of motion to radial and ulnar deviation, but also rotate in different directions. As the wrist moves from radial to ulnar deviation, the proximal row rotates from a position of flexion to one of extension. This rotation is reversed with a return to the radial deviated position. Linscheid et al[1] believe that this rotation occurs through pressure on the distal pole of the scaphoid, which is forced into flexion with radial deviation. This causes flexion of the lunate through its interosseous attachment to the proximal pole of the scaphoid. The alternative theory expressed by Weber[7] is that the helicoid shape of the triquetrohamate joint causes the distal row to translate palmarly with radial deviation, which puts pressure on the palmar aspect of the proximal row, causing it to rotate into flexion. This theory emphasizes the concept of the proximal row as the intercalated segment and suggests its control through both ligamentous and contact-surface constraints.

Classification of Carpal Instability

Carpal instability results from the loss of the normal ligamentous and bony constraints that control the wrist. This loss of stability is most prominent when a compressive load is applied to the wrist. Two types of carpal instability have been described by Dobyns and his colleagues[1,8,9]: dissociative and nondissociative. This classification system includes instability patterns that relate to trauma as well as inflammatory disease. Dissociative carpal instability can result from a tear of an intrinsic ligament. Nondissociative carpal instability can occur from a tear of the extrinsic ligaments that support the wrist, causing midcarpal or radiocarpal instability. This two-part classification system incorporates the components of a previous system, which classified instability on the basis of the location of the instability within the wrist.

The four major types of carpal instability seen clinically are dorsiflexion instability, palmar flexion instability, ulnar translocation, and midcarpal instability. Dorsiflexion instability results from ligamentous disruption between the scaphoid and the lunate, allowing the scaphoid to rotate into volar flexion. The remaining components of the proximal row, the lunate and the triquetrum, rotate into extension or dorsiflexion due to the loss of their connection to the scaphoid and its previously described effect on rotation of the proximal row. Proximal migration of the capitate, with shortening of the carpus, then causes the capitate to be displaced dorsal to the long axis of the radius. A zigzag radiolunatocapitate alignment is produced with a dorsally rotated lunate; this is called dorsal intercalated segment instability (DISI) (Fig. 3). This is the most common clinical pattern of carpal instability. In the above-noted two-part classification system this is classified as dissociative carpal instability, dorsal intercalary segment type.

Palmar flexion instability results from an opposite injury mechanism. A disruption occurs in the ligamentous support of the lunate and triquetrum. This results in volar rotation of the lunate and extension of the triquetrum, producing a VISI pattern. This is the second most common type of instability seen. Lunatotriquetral dissociation is classified as dissociative carpal instability, volar intercalary segment type.

Ulnar translocation results in an ulnar shift of the carpus. This rarely results from an injury but is frequently seen in wrists that are affected by rheumatoid arthritis.

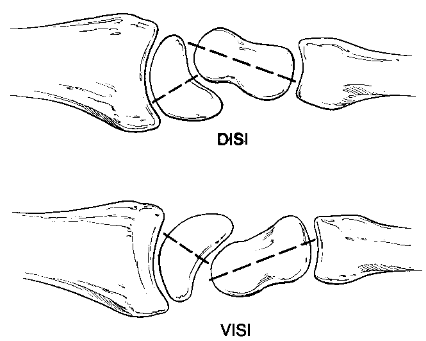


Fig. 3 In DISI, dorsal rotation of the lunate with volar flexion of the scaphoid creates a zigzag collapse deformity. In VISI, volar rotation of the lunate and extension of the triquetrum occur.

Midcarpal instability is commonly seen after a malunited fracture of the distal radius with reversal of the normal palmar tilt and secondary subluxation of the carpus resulting in instability. It can also occur with a ligamentous injury to the midcarpal joint. This is, however, a complex form of instability. Due to the limited amount of scientific data pertaining to treatment of midcarpal instability and the limited scope of this article it will not be discussed. We will limit further discussion to DISI and VISI patterns.

Carpal instabilities are also classified as static or dynamic. Static instability exists when routine radiographs clearly demonstrate loss of normal carpal alignment. Dynamic instability exists when routine radiographs are normal, but instability is demonstrated by either manipulation or active motion.

Mechanism of Injury

Mayfield et al[10] loaded cadaver wrists in extension, ulnar deviation, and carpal supination and observed the resulting injury patterns. Progressive perilunar instability was divided into four stages (Fig. 4). At the end of stage I, scapholunate diastasis is present, similar to the most

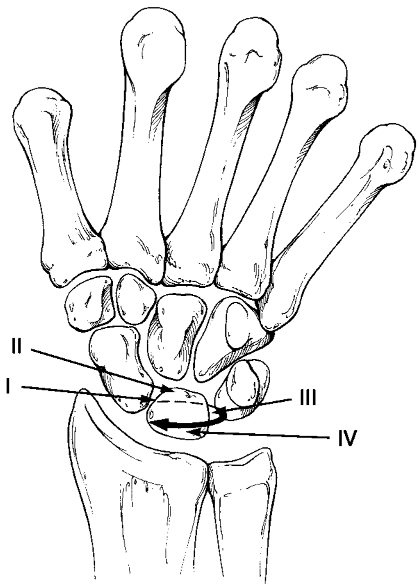


Fig. 4 Progressive perilunar instability as classified by Mayfield et al[10]: stage I, scapholunate diastasis; stage II, dorsal dislocation of the capitate; stage III, lunatotriquetral dissociation; stage IV, lunate dislocation.

frequent type of carpal instability seen clinically. As loading progresses, dorsal dislocation of the capitate occurs at stage II. Stage III is characterized by lunatotriquetral dissociation; stage IV, by dislocation of the lunate.

This experimental work pertains to injuries on the spectrum from DISI to perilunate dislocation. It correlates with the clinical mechanism of injury, which is usually caused by a fall on an outstretched arm, placing the wrist into dorsiflexion, ulnar deviation, and supination. The direction and point of application of the force and the position of the hand at impact determine whether there will be a fracture or carpal instability, as well as the type of instability.

Diagnosis

A provisional diagnosis of a specific carpal instability can be made only by obtaining an appropriate history and a detailed examination of the wrist. The provisional diagnosis can then be clarified with the use of appropriate radiologic studies.

Patients with carpal instability present with a history of pain, weakness, giving way of the wrist, and frequently a click or snapping sensation with repetitive motion. A history of injury involving extension, ulnar deviation, and carpal supination is usually present.

Physical Examination

Physical examination reveals point tenderness over the affected ligaments, such as those of the scapholunate and lunatotriquetral articulations. Pain is frequently present at extremes of motion, often with a painful click.

Specific dynamic examination maneuvers have been described by several authors to diagnose specific instabilities. Watson's test for scapholunate instability involves pressure by the examiner's thumb on the volar aspect of the distal pole of the scaphoid. This pressure reduces the collapsed position of the scaphoid. The scaphoid is maintained in this position as the wrist is brought from ulnar to radial deviation, eliciting a painful "clunk" as the proximal pole of the scaphoid is subluxated dorsally onto the rim of the radius.

Kleinman has described a "shear" test for dynamic lunatotriquetral instability. This test is performed with the wrist in neutral rotation. The examiner's contralateral thumb is placed over the dorsal body of the lunate at the edge of the distal radius. With the lunate supported, the examiner's ipsilateral thumb directly loads the pisotriquetral joint in an anteroposterior (AP) plane, creating a shear force across the lunatotriquetral joint that produces pain or a click, or both, if instability is present. Lunatotriquetral instability must also be differentiated from a tear of the triangular fibrocartilage by direct palpation. Pain on forearm rotation indicates pathologic changes in the distal radioulnar joint rather than the lunatotriquetral joint.

Radiographic Examination

Radiographic examination is obtained after clinical examination by obtaining posteroanterior (PA) neutral rotation and lateral views to evaluate the symmetry of carpal alignment and joint space. Radiolunatocapitate alignment is evaluated on a lateral view. Additional views are required to demonstrate dynamic instability patterns.

The typical radiographic findings in a patient with scapholunate dissociation include a scapholunate gap greater than 3 mm (Fig. 5). This gap is usually more noticeable on a supinated AP film of the wrist than on the standard PA view. The scaphoid is palmar flexed, resulting in a shortened appearance of the scaphoid and the cortical ring sign, which is produced by the cortex of the distal pole when viewed in cross section. Posteroanterior films taken in ulnar deviation with a clenched fist to provide a compressive load will show widening of the scapholunate interval. Lateral radiographs demonstrate the rotated position of the scaphoid and lunate into the DISI position. This is measured by the scapholunate angle, which normally averages 47 degrees (range, 30 to 60 degrees) and increases to more than 70 degrees in patients with scapholunate instability (Fig. 6).

Lunatotriquetral dissociation also has typical radiographic findings (Fig. 7). A PA view will show a cortical ring sign and a shortened scaphoid due to palmar flexion without widening of the scapholunate interval. The lunate is palmar flexed and triangular in appearance. Clear widening of the lunatotriquetral interval is not present. On the lateral view, the lunate is palmar flexed, with a scapholunate angle less than 30 degrees (Fig. 8).

Ulnar translocation can be identified radiographically by the method of McMurtry et al[11] (Fig. 9). With this method the distance between the center of the head of the capitate and a line extending the longitudinal axis of the ulna is divided by the length of the third metacarpal. In normal wrists this ratio is 0.30 ± 0.03. The ratio is smaller in wrists with ulnar translocation.

Routine radiographs are frequently normal in cases of dynamic instability. Special views should be obtained in those positions in which the patient can elicit the painful click. If these views remain undiagnostic, cineradiography should be employed to view the dynamic shift of the carpus eliciting clinical symptoms.

Other Radiologic Studies

Additional studies may be necessary, particularly in dynamic instability. Bone scintigraphy may be useful to localize the pathology and to avoid missing an occult fracture. A triphase study should be performed. A positive scan is nonspecific and cannot be used alone in diagnosing carpal instability.

Arthrography is helpful in diagnosing intraosseous ligament tears. A triple-injection study should be performed if the initial radiocarpal injection study is negative. This involves injection of contrast material into both the midcarpal and the distal radioulnar joints, which increases the sensitivity of the test.

Arthroscopy can be performed as an alternative to arthrography. It can more accurately identify intra-articular pathology, including degenerative changes and partial ligament tears, but is an operative procedure with

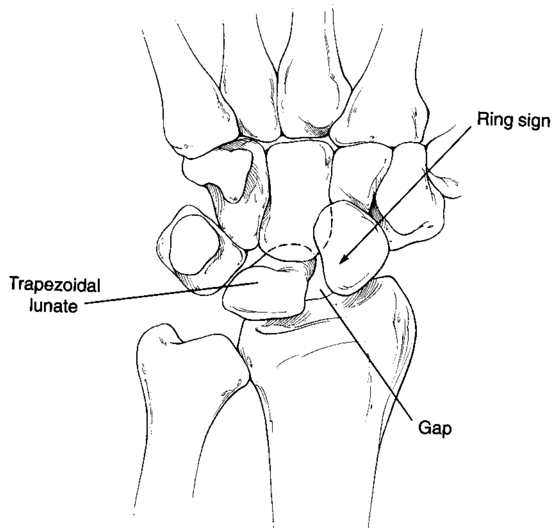


Fig. 5 Scapholunate dissociation. The scaphoid is palmar flexed, producing a cortical ring sign. A gap is present between the scaphoid and the lunate. The lunate appears trapezoidal.

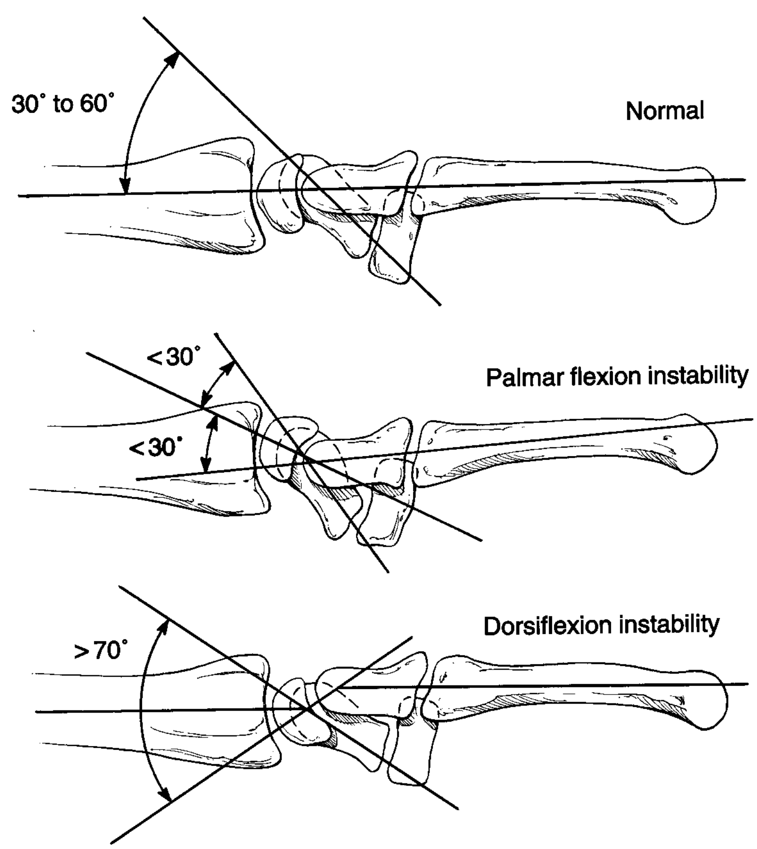


Fig. 6 Scapholunate angle measurement in normal wrist and in carpal instability.

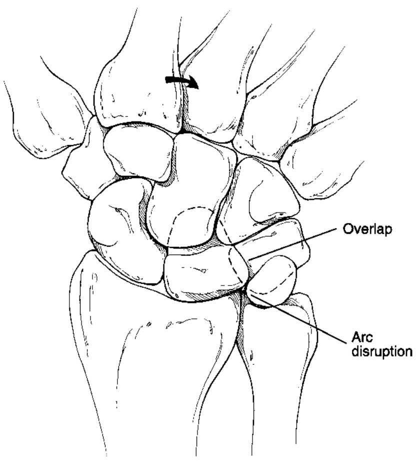


Fig. 7 Lunatotriquetral instability. Shortened scaphoid and cortical ring sign are present without scapholunate widening. Lunate appears triangular. Lunatotriquetral widening is not present.

obvious risks not present with arthrography and noninvasive tests.

Computed tomography is not useful in the diagnosis of carpal instability. The usefulness of magnetic resonance imaging is as yet unproved, but is evolving as better coils improve resolution.

Treatment

The treatment of carpal instabilities is based on several factors relating to the time of presentation after injury, the degree of ligamentous injury, and the presence of degenerative change in the wrist. Acute injuries are capable of ligamentous healing if diagnosed early and treated appropriately. Initial evaluation should include routine radiographs; if these are normal, aspiration is performed to look for intra-articular blood or fat droplets indicative of an occult fracture. If the aspiration is positive, a diagnosis of ligament tear or occult fracture is made, and immobilization is instituted for 6 weeks. If symptoms persist or a clinical stress examination demonstrates instability, arthrography is indicated. A positive arthrogram indicates that arthroscopy should be performed to fully evaluate the ligament damage, followed by either arthroscopically guided reduction and pinning or open reduction and ligament repair. Open repair is preferred to closed percutaneous pinning except in the case of acute ligament injuries. The open repair of subacute injuries diagnosed at 4 weeks to 6 months gives excellent results when torn intercarpal ligaments are reattached.[12]

In our opinion, all acute tears that present with abnormal initial radiographs should be treated with arthroscopic evaluation and either arthroscopically guided reduction and pinning or open reduction and ligament repair.

Chronic tears, defined as those present 12 months or more after injury, have more significant carpal changes and will not respond to closed treatment or ligament repair. The rigidity of the carpal collapse and the degree of secondary degenerative change must be determined, since they will influence treatment alternatives. Chronic scapholunate instability can be treated by ligament reconstruction and capsuloplasty or intercarpal arthrodesis. If the collapse deformity is reducible, ligament reconstruction and supplementation by a dorsal capsulodesis, as described by Blatt,[13] may be considered (Fig. 10). If a fixed deformity is present, any attempt at ligamentous reconstruction will fail; therefore, intercarpal arthrodesis should be performed to stabilize the relation between the proximal row and the distal row. This is accomplished by reduction of the scaphoid and maintenance of this position by means of scaphocapitate or scaphotrapeziotrapezoid arthrodesis (Fig. 11).

Intercarpal fusion is preferred for manual laborers and athletes due to the repetitive high stress applied to the wrist. If advanced degenerative

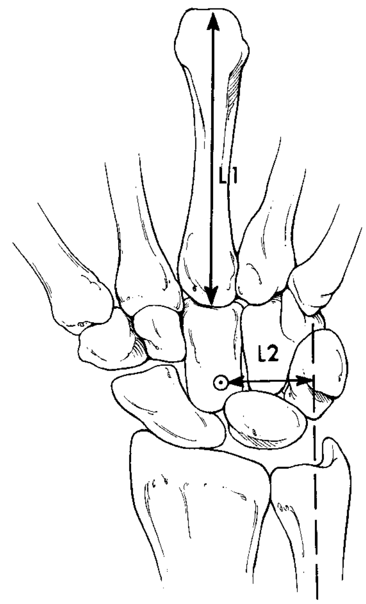
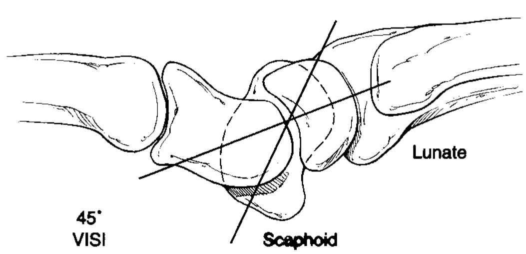


Fig. 9 Ulnar translocation can be identified radiographically from the ratio of the distance between the center of the capitate and a line along the longitudinal axis of the ulna (L2) divided by the length of the third metacarpal (L1). In normal wrists this ratio is 0.30 ± 0.03; it is decreased in wrists with ulnar translocation.

Fig. 8 Lunatotriquetral instability as seen in lateral view. The lunate and scaphoid are palmar flexed with a reduced scapholunate angle.



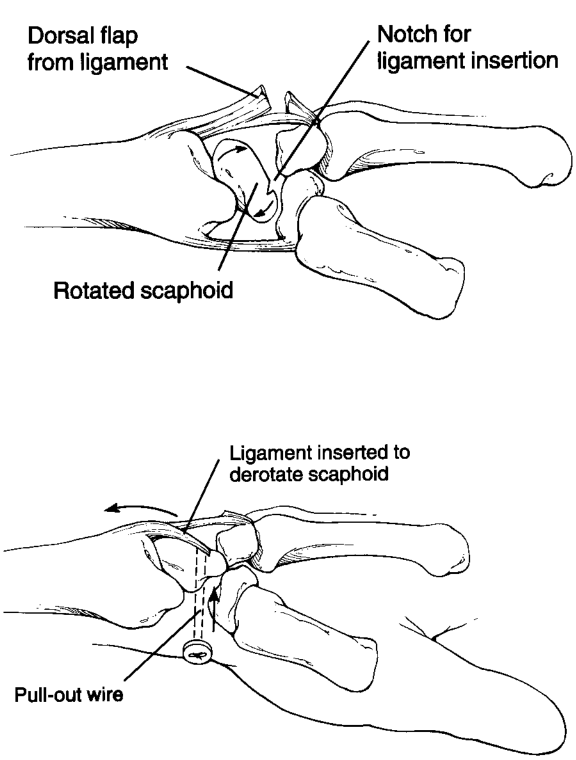


Fig. 10 Technique of dorsal capsulodesis. **Top,** A proximally based flap of dorsal wrist capsule is raised, and a notch is created in the distal pole of the scaphoid. **Bottom,** The scaphoid is derotated, and the capsule is inserted into the scaphoid by a pull-out wire to maintain the reduced position.

change is present at the time of evaluation, radiocarpal or midcarpal arthrodesis should be performed, rather than ligament reconstruction or intercarpal arthrodesis, which will continue to transmit force across a degenerated joint.

Lunatotriquetral tears are treated with a similar approach. The triangular fibrocartilage must be assessed and treated as well as the intraosseous ligament. Late instability will require reconstruction of the extrinsic radiotriquetral ligament as well as the lunatotriquetral intraosseous ligament. Lunatotriquetrohamate fusions are recommended for rigid VISI instability (Fig. 12). Ulnar abutment must be considered in patients with positive ulnar alignment and should be treated by ulnar shortening at the time of arthrodesis.

Summary

Injury to the ligaments of the wrist is a frequent consequence of a fall on the wrist. The accurate early diagnosis and treatment of the resultant carpal instability can significantly improve the functional outcome and prevent long-term disability. All "wrist sprains" must be assessed with a careful history, physical examination, and radiographic examination. Additional radiologic studies should be performed as indicated. Carpal instabilities diagnosed within 4 to 6 weeks of the injury are treated by arthroscopic evaluation and either closed reduction and arthroscopically guided pinning or open ligament repair. Injuries diagnosed between 6 weeks and 6 months after injury are treated by open ligament repair and ligament augmentation. Patients treated between 6 and 12 months after injury are treated by either ligament reconstruction or intercarpal arthrodesis, depending on the ability to restore normal carpal alignment. Most patients treated longer than 12 months after injury require intercarpal arthrodesis unless diffuse degenerative change is present, in which case radiocarpal arthrodesis is indicated. The patient's age, occupation, and avocations also influence the treatment algorithm, favoring arthrodesis for those who apply significant stress to the wrist.

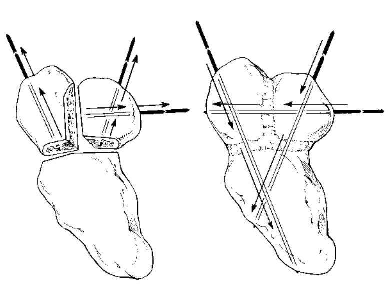


Fig. 11 Scaphotrapeziotrapezoid arthrodesis.

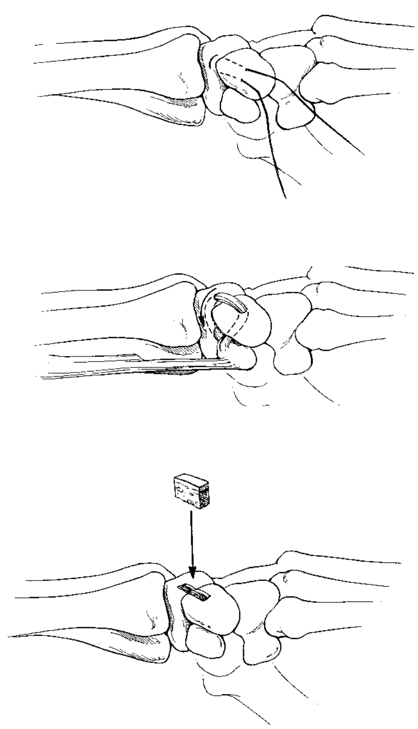


Fig. 12 Treatment alternatives for lunatotriquetral instability. **Top,** Ligament repair. **Middle,** Ligament reconstruction. **Bottom,** Arthrodesis.

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