A Contribution to Wrist Surgery

Philippe Saffar, M.D.¹

¹ French Institute for Surgery of the Hand, Paris, France

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Address for correspondence and reprint requests Philippe Saffar, M.D., Institut Français de Chirurgie de la Main, 5, rue du Dôme, Paris 75116, France (e-mail: psaffar@ifcm.org).

The story of hand surgery began in France with Marc Iselin. He was the first to head a unit devoted only to hand surgery at the Nanterre Hospital, near Paris, in 1955. He also wrote the first book on hand surgery in 1928, but the wrist was not really in the scope of hand surgeons at that time. Then the French Society was created by four surgeons and an anatomist: R. Tubiana, R. Vilain, J. Michon, J. Duparc, and P. Rabischong, respectively. It was first called the GEM (Groupe d'étude de la Main)—Group for Study of the Hand—that changed to French Society for Surgery of the Hand.

During my surgical training as resident and chief resident, I had the opportunity to obtain my specialization in orthopedics and traumatology and also in plastic surgery. It was very useful when I concentrated my practice on hand surgery where the two specialties converge. During my stay of 3 years as a chief resident in the unit of my mentor Dr. Raymond Vilain (1970 to 1973), he had the idea to create the first hand emergency unit in Europe called SOS-Mains. It was a new concept, and in a few months, we were inundated with a flood of hand and upper limb emergencies. We were on duty every third day, and with the emergence of microsurgery, all the nights were occupied. Subsequently, these types of centers were created in France and then in many European countries. There is now an association called the Fédération Européenne des Services d'Urgence de la Main (FESUM) or European Federation of Emergency Hand Treatment Units.

Subsequently, I have spent as an assistant and then as a surgeon in the hospitals of Paris for 17 years in the unit of R. Vilain. At the same time, I also worked in a private hospital of orthopedics and traumatology, where I was in charge of the upper arm, treating building laborers. There, I had the opportunity to treat 120 cases of the Kienböck disease and a high number of cases of wrist problems such as fractures, dislocations, carpal instabilities, and hundreds of scaphoid problems. I followed the evolution of techniques and went to many meetings in France, Europe, the United States, and Asia. In the beginning of the 1980s, I along with M. Merle, G. Foucher, and A. Gilbert went to China twice in 2 consecutive years as a French mission to study the status of hand microsurgery in the country. We visited the hospitals in Beijing, Shanghai, Guangdong, and Chengdu and discovered

a very sophisticated microsurgery practice in this country ahead of the development of microsurgery in the world.

I became a member of the French Society of Orthopedic Surgery and Traumatology and also a member of the GEM in 1973. In 1985, I became a member of the American Society for Surgery of the Hand, and since then, I have been attending each of its meetings. Also, I became a member of the British, the Japanese, the Argentinian, and the South American societies.

My interest in wrist surgery began early and, in 1982, I described a technique of replacement of the lunate in the Kienböck disease by the pedicled pisiform. I also published several articles on the wrist and participated and communicated extensively in the French and international meetings. Since the creation of "International Wrist Investigator's Workshop" at the Mayo Clinic in 1984, I have attended it each year and have presented papers at almost each of its meetings.

In 1985, I along with R. Tubiana, A. Gilbert, and R. Lisfranc created the first private group for hand surgery called "French Institute for the Hand." The group lasted for 10 years, and we were 10 hand surgeons at the end of 1995. For different reasons, the group split and I created the "French Institute for Surgery of the Hand" in Paris and altogether we are now 11 hand and upper arm surgeons. For the last 25 years, we have hand fellows (8 fellows each year) coming from different countries and continents. They spend 6 months with us, and they participate as assistants in the operating room and in the staff meetings and consultations. Several papers were prepared and presented at these meetings during their stay.

I was able to complete my first book in French on "carpal injuries" in 1989 (Springer-Verlag, Paris, France). It was translated in English and in Japanese. Other books that were edited or authored by me or in collaboration are listed in ►Table 1. I was also the Editor-in-Chief of the French *Journal for Hand Surgery—Chirurgie de la Main*—from 2001 to 2008.

This has been my contribution to hand and wrist surgery. I was asked to detail it in an immodest way. I have now stopped my surgical activities but hope to continue to publish.

Table 1 Books Edited

Carpal Injuries (In French). Ph.Saffar Paris. Springer-Verlag. 1989. 205 pages.
Arthritis of the Base of the Thumb. Expansion scientifique Française. (In French) Ph. Saffar Paris. 1990. 214 pages
Carpal Injuries. (In English and in Japanese) Ph. Saffar Paris. Springer-Verlag. 1990. 199 pages.
Wrist Imaging(In English). Brunelli, and Ph. Saffar Paris. Springer-Verlag. 1991. 214 Pages
Wrist Arthroscopy (In English). J.Stanley and Ph.Saffar. London. Martin Dunitz Ltd. London. 1994
Handgelenkarthroskopie. J.Stanley and Ph.Saffar. Chapman and Hall. Weinheim. 1994
Fractures of the Distal Radius. Ph.Saffar and W.P.Cooney. London. Martin Dunitz Limited. 1997. 320 pages
Current Practice in Hand Surgery (Medical Book Award by "The Royal Society of Medecine" in London. UK). Ph.Saffar, P.C. Amadio, and G. Foucher London. Martin Dunitz Ltd. 1997. 440 pages
Joint Stiffness of the Upper Limb. S.A. Copeland, N. Gschwend, A. Landi, and Ph. Saffar London. Martin Dunitz Ltd London. 1997. 401 pages

Carpal Instability

Scapholunate Instability

My first interest in wrist surgery was for carpal instability. R. Linsheid and J. Dobyns had well described in their 1972 article¹ that this injury was not well known at that time and treatment was not documented. J. Taleisnik has made a perfect description of the carpal ligaments. Aware of the importance of the ligaments, we performed sequential ligament sections already done by others. It allowed us to understand what are the main ligamentous supports of the wrist. In parallel, the articles on wrist and carpal biomechanics were being published. It began to be clear that the isolated rupture of the scapholunate ligament was not sufficient to produce a scapholunate dissociation and that it needs some sort of laxity or tear of the volar plane of the carpal ligaments associated to obtain a scaphoid rotation or a dissociation. The different motions of the carpal bones were described and the coaptation of the bones when making a fist provide a global motion of the carpal bloc.

In 1994, we performed cineradiographies that demonstrate that the real wrist axis of motion of the wrist was an oblique plane from dorsal–radial deviation to palmar–ulnar deviation. It is in this plane that the wrist is used for what was called the dart-throwing axis (published in 1994).² The amount of motion is maximum in this plane, better than in flexion-extension and radial-ulnar deviation. It is the plane used when striking with a hammer or throwing something.³

The mechanism of scapholunate ligament tear was well described by Mayfield³ with a fall on an outstretched wrist and impact on the thenar eminence. It is the most frequent mechanism, but other mechanisms of SL tear are possible and we described a fall backward with the hand behind the axis of the body and an impact on the hypothenar eminence. The injuries begin at the lunotriquetral ligament, go through the midcarpal joint, and end in the SL ligament, which was injured or not. These traumas cause ligament tears in young patients who are younger than 40 or 50 years, when the bones are stronger than ligaments, but they produces distal radius fractures in older patients for the opposite reason. In the intermediate ages, the two types of injuries may be combined.

It is particularly true for intra-articular fractures and present in 70% of the radial styloid fractures.

Diagnosis of an SL Tear

The diagnosis is clinical, such as pain at the SL interval, clicking, and Watson sign, and radiological, gap between the two bones and increased SL angle in a strict lateral view. The gap may appear only through dynamic views that seem useful for a better diagnosis in dynamic instabilities. Emphasis has been put on the use of arthroscopy, but we have been using arthro CT scan for the last 30 years. I have performed it with Dr. Pigeau, whose technique is meticulous. The CT scan should be performed within 20 minutes after the injection is administered in strictly sterile conditions in the following three locations: radiocarpal, midcarpal, and distal radioulnar joint (DRUJ) joints. A good technique is vital, and we obtained very good images of ligaments, cartilages, and bones (→Figs. 1 and 2). It is much better than magnetic resonance imaging (MRI) and less invasive than arthroscopy.

Linsheid, Dobyns, Taleisnik, Howard, and I began trying to treat these conditions using complex ligamentoplasties. These repairs were performed using often two approaches and several holes in the carpal bones. As always in this type of plasties, tension during ligamentoplasty was difficult to apply. If too tight, the carpal motion decreased, and if too lax, the gap between the bones reappeared. Often, after

Figure 1 Scaphoid rotation with a good cartilage.

Figure 2 Scapholunate ligament tear.

removing the k-wires or with the passage of time, the scapholunate gap and the scaphoid rotation recurred. Progressively, these procedures were abandoned even by the precursors. The Blatt capsuloplasty was added, but in our hands, it was never an isolated procedure. It was combined with ligament repair.

The scapholunate instability began to be diagnosed earlier and this allowed an initial reconstruction. This was done in the beginning using sutures that were passed through tunnels in the bones, a difficult technique, which was simplified by the advent of bone anchors. The condition in all these techniques was the reducibility of the scaphoid. This element was conditioned by two items: (1) the time elapsed since the initial injury and (2) the extent to which the ligament was destroyed. Usually with time, the scaphoid becomes increasingly difficult to reduce. But even in some early cases, the rotation of the scaphoid is fixed because of several torn ligaments. This has been proved by numerous experimental works. My profound conviction is that if the scaphoid is difficult to reduce, the distraction forces on the soft-tissue repairs will be so significant that they will not stand against these forces and the ligament laxity will recur. This conviction was supported by clinical experience. What was the aim? Reposition of the scaphoid proximal pole in its fossa to prevent osteoarthritis (OA) (► **Fig. 1**).

In very recent cases, reduction of the scaphoid may be obtained by external maneuvers followed by percutaneous pinning. This may be helped by an arthroscopic control. We have recently used a scapholunate screw to fix during first year of the ligament repair. It seems to improve the chances for stability. Attention should be drawn when there is a distal radius fracture. Scapholunate ligament tear is often combined with the fracture of the distal radius, specially, with intra-articular fracture, and with the most significant frequency, the radial styloid fractures.

The role of arthroscopy in the treatment of SL instability seems to be increasingly important. We have to wait for a long time to know if this is valuable. Other authors have published SL ligamentoplasties, but X-rays were impressive in demonstrating big holes in the two bones and works on complications of bone devascularizations have been published.

On the basis of a principle already used in the knee, a ligament reconstruction using a graft composed by a bone-ligament-bone unit may be performed. The first description is due to A. P. Weiss in 2007. Another type of graft has been preferred and described by Cuenod. It provides a strong trapezoidal-metacarpal ligament, which is easy to harvest. Fixation of an exactly fitting bone-ligament-bone autograft taken from the trapeziometacarpal joint II is done with 1.2-mm screws into the troughs. This is a careful planned procedure. Indication is reserved for cases when the scapholunate gap is not greater than 3 to 4 mm.

A Viegas capsuloplasty using the dorsal intercarpal ligament is also described.

The Brunelli technique was published in 1995, a technique using a strip of FCR to perform a scaphoid tenodesis in a reduced position. This has been used and modified by M. Garcia-Elias and J. Stanley using the same principle but without a radius support. The theory of G. Brunelli was that the responsibility of the carpal instability was the rupture of the distal scaphoid scaphotrapezotrapezoidal (STT) ligaments. In fact, it is not because one can straighten up the scaphoid using a distal tenodesis that the cause of the instability is distal as theorized by G. Brunelli. Results of this technique were positive and were published,⁴ which provides a new life to ligamentoplasty.

Another possibility provided mainly by K. Watson was a limited carpal arthrodesis. It is possible when the scaphoid is reduced, to fix it in its correct position (~45 degrees of radioscapoid angle) using an arthrodesis with its base composed of the trapezium and trapezoid. The arthrodesis was created and widely used by K. Watson and followers. It has the advantage to restore the carpal height but the disadvantage to modify the transmission of forces to be maximum on the proximal pole of the scaphoid and possibly create a hyperpressure and a cartilage wear at this point. Several articles pointed out the disadvantages of this technique. We have also used and abandoned the SL arthrodesis because of the high rate of nonunion. Our choice was the scaphocapitate (SC) arthrodesis (► **Fig. 3**). We chose to perform SC arthrodesis for the following reasons:

1. Reduction and orientation in the space of the scaphoid are easier to settle than for STT arthrodesis.
2. There is only one surface to heal instead of three.
3. There is a large surface of contact between the two bones and a better rate of healing.

We have operated on 58 patients: 12 women and 46 men and reviewed them with a follow-up of 28.5 months in average. Pain which was present for all strains preoperatively was intermittent and climatic postoperatively. Flexion-extension loss was 5 degrees, from 93.5 to 88.5 degrees and lateral deviations loss was 11.4 degrees, from 50.9 to 39.5 degrees. Strength has increased in 12% patients.

Special Features of SC Arthrodesis

The midcarpal joint is removed because of STT arthrodesis, but the SC bloc may slide relative to lunate and hamatum bones during carpal motion, which is visible on dynamic

Figure 3 Scaphocapitate arthrodesis.

series and allows better lateral amplitude. The radial part of the midcarpal joint is fixed, but motion between triquetrum and hamatum is still possible in radial and ulnar deviations.

The thumb column is completely free and so is the STT joint.

We recommend this type of arthrodesis for SL instability when the scaphoid is difficult to reduce or for failures of a soft-tissue procedure or for a heavy worker.

In 18 cases, we have also used scapholunocapitate arthrodesis.

Indications of this technique were an OA of these joints, sequelae of carpal dislocations, and failure of an attempted scapholunate arthrodesis. It has been combined in 11 cases with a styloidectomy.

Having operated on more than 300 SL injuries without OA, we have now a simple classification in three stages: (1) scapholunate ligament tear, (2) SL ligament tear + scaphoid rotation, and (3) SL dissociation. At each stage, a different treatment is applied: (1) ligament repair or reattachment, (2) soft-tissue repair after reduction and pinning, and (3) SC arthrodesis except very early repair and easily reducible scaphoid.

The evolution of scapholunate advanced collapse has been perfectly described by K. Watson. If we agree for the use of a four-corner arthrodesis with scaphoidectomy then we are not systematic. We also used capitulunate arthrodesis and three bone: capitulunohamatum arthrodesis (CLH). Capitulunate arthrodesis is known for a large number of nonunions and this we noted in our first cases. My partner Dr. Sokolow has studied these cases and assessed that nonunion was present when there was a significant ulnar shift of the lunate relative to the head of the capitates. An index was described and nonunion was almost certain when the capitulunate angle or drift was greater than 20 degrees (angle between the third

metacarpal axis and the center of the metacarpal base to the center of the lunate bone).

For the three-bone arthrodesis (CLH), indications for the author [Delattre] are a shortening arthrodesis, removing the scaphoid, and the triquetrum. This may allow a better motion. My indication is when there is a Viegas type 2 lunatum, then I prefer not to shorten the carpus but insert a graft to maintain the carpal height. Removing the triquetrum is not indicated because recently Garcia-Elias has demonstrated that there is a large distribution or proprioceptive nerve fibers in this area and that this bone is useful for proprioception.

In some cases of SLAC 2, proximal row carpectomy may be indicated. We have studied the results of this procedure with more than 10 years of follow-up in average. In 80% of the cases, the results after 2 years are favorable and there is often a remodeling with time of the capitate head that tend to occupy the radiocapitate joint. In 20% of the cases, the head of the capitate is rapidly destroyed and the patient is stiff and painful. I think it is a vascular problem. In some MRI scans, when there is a hypovascularization of the lunate, the head of the capitate is also hypovascularized. The removal of the first row may have a consequence on the vascularization of the capitate.

The scapholunate instability is the first provider of post-traumatic OA of the wrist.

Lunotriquetral Instability

As for the mechanism of the carpal injuries, the pattern usually admitted² is a fall on the thenar eminence and a progression of the ligament injuries ulnarward. I have experimented and showed that a fall on the hypothenar eminence (like in a fall with the hand behind the body) would produce first a lunotriquetral disruption and then go through the midcarpal joint to end in the scapholunate joint (► **Fig. 4**).

Figure 4 Lunotriquetral disruption and subsequent course of dissociation along the lines marked by the arrows.

There is the frequent association with other local injuries: TFCC injuries and SL dissociation. Things get worse if there is a long ulna with hyperpressure on the carpus through a hole in the TFCC. A good result may be obtained only if all the features are identified and treated.

Ligamentoplasty is recommended. Lunotriquetral limited arthrodesis provides several nonunions. If performed, a graft should be inserted and a fixation made using two screws.

Midcarpal Instability

The causes of misdiagnosis have always been of great interest and I have seen in consultation lots of hypermobile young girls presenting wrist pain, clicking, and discomfort. They have been often diagnosed with SL instability. It was easy to demonstrate that they had wrist hypermobility on both sides and a slight trauma caused all the troubles. They also presented ankle or knee sprains. Some clinical maneuvers completed the diagnosis examination.

But, after conservative treatment, I had to operate on 20 cases of patients of 20 years of age with a palmar instability, which is not an easy decision. The surgical treatment consisted (1) a VISI reduction and a radiolunate pinning in extension and then a transverse closing of the two branches of the deltoid ligament reinforced by a tendon graft of palmaris longus interwoven with the deltoid ligament (► Fig. 5). They were reviewed after an average of 63 months with good results. Pain had completely disappeared except in two cases. Motion and grip were normal and the characteristic “clunk” had disappeared in most cases, and in some cases, recurred but without pain. In other older posttraumatic cases, a limited midcarpal arthrodesis was performed.

Proximal Instability

Few cases of posttraumatic instability have been treated using radiolunate arthrodesis after lateral reduction. Alternatively, a ligamentoplasty with a strip of the extensor carpi ulnaris through the Lister tubercle was performed to oppose the carpal ulnar shift.

Scaphoid

All has been said about the scaphoid and, in particular, the need to make it heal in a good position and to prevent malunions.

Figure 5 Ligamentoplasty using the palmaris longus to close the Poirier space.

I am not sure of the compressive action of the Herbert screw with time, but its headless design is certainly a good point. The corticocancellous graft and the triangular opening of the nonunited bone is mandatory to regain scaphoid length and good carpal kinematics.

Anyway, there are often malunited and shortened scaphoid. When it has been difficult to make this bone heal, the decision to cut it again by osteotomy may be difficult. Residual pain and bad kinematics may be an indication to a palmar osteotomy and graft and a good fixation. The result is often worth the risk.

Proximal pole necrosis is another problem. We do not use an implant because the OA is between the distal scaphoid and the tip of the radial styloid. Our solution is to remove the proximal pole necrosed and perform an arthrodesis between the distal scaphoid and the capitates plus a limited styloidec-tomy to remove the zone of conflict (► Fig. 6).

Distal Radial Fractures

I have seen progression of surgery in treatment of distal radial fractures. What was reduction and cast, and sometimes pinning, initially would get transformed in a sophisticated surgical treatment. Probably, it was in the beginning of a treatment addressed to elderly people that there was a tolerance toward malunion and a decreased function. Nowadays, it seems unbearable to have a slight deviation and every decrease in function is experienced as the result of a bad treatment.

Among the plates and other devices proposed, we have chosen the fragment-specific approach, particularly for intra-articular fractures. It allows support to impacted bone fragments and put back them in place. We have used bone grafts

Figure 6 Arthrodesis between distal scaphoid and the capitates with resection of the proximal pole.

for some time; but with the “clip,” we can keep those fragments in place. There is a solution for each type of complex fracture and the lateral approach allows to check the reduction of volar and dorsal fragments.

The use of these devices is particularly useful for intra-articular malunions. We began to treat intra-articular malunions performing intra-articular osteotomies and reduction of each displaced fragment followed by an individual fixation. The conditions for this treatment are a careful analysis of the initial fracture and of the current situation using CT scans and arthro CT scans to know the remaining cartilage status. The malunion should not be older than 1 year because after that time, it is difficult to find the initial fracture line. Some extra bone due to the callus should be resected to obtain a good reduction and a good bone reconstruction. An extra-articular malunion may be associated and be treated in the same time. Surgery is difficult but rewarding if the cartilage is still present.

There are other treatments of intra-articular distal radius malunion. When there is a radioscapoid involvement, a proximal row carpectomy or a four-corner arthrodesis with scaphoidectomy may be indicated to resolve the radial conflict. If it is the lunate fossa that is destroyed by a die-punch fracture, for example, a radiolunate arthrodesis with an intercalated graft to regain the height is done (→Fig. 7) I have used a sliding graft and a simple fixation to restore this joint (→Fig. 8). When the two articular facets are destroyed, a total wrist arthrodesis is not necessary and a radioscapulolunate arthrodesis has a good indication. This has been improved by resection the distal scaphoid.

As for all joints, the aim of every surgery is to retain a certain amount of motion in the wrist, which is important if not painful. This maintains the automatic tenodesis motion of the fingers and we always try to avoid total wrist arthrodesis, which is too much performed, especially by orthopedists.

Figure 7 Radiolunate arthrodesis.

Figure 8 A sliding graft from the dorsal aspect of the radius for a radiolunate arthrodesis.

Long Ulna or Ulna Impaction Syndrome

Long ulna may be congenital or acquired. It is usually the sequela of a distal radius fracture. Pain is located at the ulnar side of the wrist after distal radius fracture due to a radius-ulna length discrepancy or a problem at the DRUJ.

Clinically, it is marked by local pain and pain at pronosupination and in ulnar deviation. There is often a distal ulna protruding dorsally and then a supination decrease. An increased mobility of the distal ulna may exist.

Two types of treatment may be indicated:

1. Radius lengthening: The distal radius malunion may be corrected by an osteotomy and a lengthening bone graft to realign the distal radius.
2. Ulna shortening: The classical approach is a shortening osteotomy and a plate fixation. Nonunion is frequent and removal of hardware is mandatory.

We have used since many years a new shortening osteotomy. The aim is to restore a good length to the ulna relative to the radius and a congruity of the DRUJ if the joint articular cartilage surfaces are intact and the ligament present. A long oblique osteotomy is used

Technique of Oblique Osteotomy

A longitudinal approach is performed on the ulna crest. The length of this approach should depend on the preoperative calculations. Muscles are elevated from the bone to allow ulna osteotomy. An oblique osteotomy of the ulna with a powered saw is performed starting at the radial and distal border 2 cm proximal to the DRUJ to reach the proximal and ulnar border of the bone. Then, one may make the two fragments slide to shorten and slide laterally to obtain congruity of the DRUJ (→Fig. 9). This should be made keeping in mind that the fragments should have a large contact to enable the osteotomy to heal easily. Clinical and radiological tests are performed. Palpation of the DRUJ and motion in pronation and supination are tested with the two fragments opposed by clamps. Bone exceeding the bone limits may be resected but is rarely needed if the osteotomy is long enough. Fixation is performed using three screws (→Fig. 9) or more.

Figure 9 Model for the ulna oblique osteotomy.

Depending on the treatment performed on the radius, rehabilitation begins early after 3 weeks with movements of pronation and supination.

We have had no nonunions, no cases of infection, and no complex regional pain syndromes. Rehabilitation was necessary.

Fifteen cases have been operated on. The average age was 32.2 years.

Pain was reduced. Pronosupination was normal pre- and postoperatively. Wrist motion in flexion, extension, and radial and ulnar deviation was not statistically modified. Strength was constantly improved by 30% on average. Healing was obtained in 40 days on average.

On postoperative lateral X-rays, the two diaphyses are superimposed and ulnar variance is within normal range. Results of this technique should be compared with other techniques in terms of simplicity and healing rate. The techniques of Darrach in elderly people and Sauvé-Kapandji in young patients provide good results for the sequelae of distal radius malunion or congenital disease. The advantage of oblique ulna osteotomy is that healing is fast and removal of devices is not necessary. The disadvantage is the length of the scar.

We have used this technique each time a shortening of more than 4 mm was necessary. When a shortening of less than 4 mm was necessary, we used the intra-articular oblique osteotomy.

This technique has been described by Comtet et al⁵ and then Sennwald et al⁶ for other purposes. A dorsal approach of the DRUJ is performed along the ulna crest. Arthrotomy is done proximal to the triangular ligament insertion.

An oblique intra-articular osteotomy is then performed, beginning at the fossa proximal to the insertion of the triangular cartilage and directed obliquely at approximately 60 degrees radially and proximally like for a Bowers procedure. The fragment of the detached ulna head is slid up of 3 to 4 mm and two screws are inserted from the ulnar side of the bone into the fragment taking care not to go through the cartilage (► **Fig. 10**). Pronosupination movements are done to check the possibility of a complete motion.

A total of 36 patients were operated on and reviewed: 18 women and 18 men. The average age was 40.5 years. The average follow-up was 16.2 months (7 to 58 months). There were 15 manual workers (► **Table 2**).

Time elapsed for pain being only climatic or intermittent after surgery was 9.15 weeks, including two chronic regional pain syndrome (6.06 weeks without CRPS).

Figure 10 Intra-articular oblique osteotomy fixed by two screws.

Strength increased from 0 to 20% (nonsignificant). The Quick DASH score was 2.4 (excluding two CRPS).

Radiographically, the ulnar variance was +2.25 preoperatively and -0.55 postoperatively.

The osteotomy always healed in 6 weeks and return to the same work was effective in all cases. This is a simple and reproducible technique with short immobilization. Results are constant and healing fast. Return-to-wrist function is fast and stable.

Madelung Disease

This complex forearm and congenital wrist deformity is not always functionally disturbing. Of the more than 50 cases that we have seen in consultation, only 22 had to be operated on. The main indications were pain, decrease of pronosupination, and cosmetic concerns. The more deformity exist, the younger the onset of problems.

The deformity is predominant at the wrist but the forearm is part of the deformity. The curvature increased at the radius shaft, deformity of the ulna, which is short at the forearm but

Table 2 Results of the Oblique Intra-articular Osteotomy

	Preoperatively	Postoperatively
Pain	3.33	0.25 (significant)
Flexion	57	59
Extension	61	65 (nonsignificant)
Pronation	73	74
Supination	85	84

longer than the radius and dorsally protruding. This has to be considered while focusing on the wrist.

The deformity at the wrist is caused by an early fusion of the medial half of the distal radius growth plate. This early epiphysiodesis ends up during growth in a palmar and ulnar angulation of the distal articular slope of the radius. The condition may be unilateral or bilateral but often asymmetrical.

Madelung deformity may be congenital or acquired. Madelung deformity may be posttraumatic—seemingly benign trauma of the growth plate, more often around age 11, secondary to an infection of radius distal end, and caused by multiple exostosis disease (Ollier disease) at the forearm distal end.

There is a posterior protrusion of the ulna which seems to be too long. In fact, it is the distal radius which is in flexion. Elbow extension may be limited. Importance of radiolunate ligament in the young patient should be stressed.

Radiological Signs

Anteroposterior (AP) and lateral X-rays of both wrists, AP and lateral comparative forearm views where elbow and wrist are visible are performed.

- The slope of the radius distal articular surface is increased, presenting two facets, and the lunate facet presents the most significant slope.
- The deformed ulna seems too long. It may demonstrate an abnormal anterior curvature.
- There is an abnormal position of the DRUJ. Posterior displacement is partially or totally reducible during early adolescence, but fixed in adults.

There is a carpal deformity: Carpus is anteriorly subluxated and lunate deformed presenting a triangular proximal surface with two slopes.

In elderly people, OA may be present with remodelling of distal ulna, osteophytes, and radioscapoid and ulnocarpal joint spaces thinned and defects on the lunate.

Patients older than 60 years are referred for extensor tendon ruptures or carpal tunnel syndrome.

Treatment for Adults

- Radius osteotomy: bone section and reorientation of the radius distal epiphysis for correction of distal radial slope and palmar inclination. A slight rotation in supination is associated to improve the DRUJ congruity.
- Oblique shortening osteotomy of ulna with sliding and relaxation of the distal ulna to increase DRUJ congruity (►Fig. 9).
- Treatment of DRUJ: stabilization of this joint by different techniques depending on age or Sauvé-Kapandji procedure.

We think that treatment of the two bones is necessary.

Treatment for Children

- Epiphysiodesis: a limited or total growth plate resection and growth curves should be taken into account.

- If epiphysiodesis is not sufficient to correct deformities, an osteotomy should be performed as for an adult.

Radiolunate Ligament

- Resection of this ligament is a preventive treatment of carpal deformities. It should be performed as early as possible.

Kienböck Disease

Lichtman stages 1 and 2 should be treated using decompressive treatments: joint leveling procedure when there is a radioulnar discrepancy, or capitate shortening when the two bones are of equal length. Intraosseous synovial cysts are frequently misdiagnosed as Kienböck and they should not receive the same treatment.

At stages IIIa and IIIb, I have used the transfer of the pedicled lunate to replace the necrosed and collapsed lunate. At stage III, there is a lunate fragmentation without (IIIa) or with carpal instability (IIIb). Extracarpal hyperpressure may be due to a short ulna when present and intracarpal hyperpressure by pressure of the capitate on the lunate in case of carpal collapse.

There is a specific vascularization of the pisiform bone: the cubitodorsal artery, branch of the ulnar artery. The vascularized pisiform bone may be transferred in place of the excised lunatum.

The aims are to decrease pain when keeping the mobility, to replace a dead bone, to maintain the distance between scaphoid and triquetrum and radius and capitulum, and to prevent the carpal collapse.

We transfer the pisiform based on the upper pedicle, which is the cubitodorsal artery, a dorsal branch of the ulnar artery. This artery originates 4 cm proximal to the proximal crease of the wrist and may have two patterns.

1. A single vertical artery running distally and reaching the proximal end of the pisiform and connecting the periosteal vascular circle around the pisiform (►Fig. 11).
2. A horizontal artery irrigating the ulnar skin of the distal forearm and from which originate two or three arteries, branching perpendicularly and running distally to the pisiform and its periosteal vascular circle.

Considering the relative size of pisiform and triquetrum, the height of the two bones is relatively similar, but the width, length, and volume of the pisiform are smaller than the triquetrum.

Approach and Dissection of the Pisiform

- The incision is made parallel to the flexor carpi ulnaris (FCU) tendon at the anteromedial aspect of the forearm, beginning 4 cm proximal to the distal wrist crease. At the level of distal wrist crease, it is curved radially and continued distally for 2 cm into the palm.
- The FCU tendon is retracted radially or ulnarly. The cubitodorsal artery, which branches off of the ulnar artery

Figure 11 The cubitodorsal artery and branch of the ulnar artery.

becomes apparent. A vessel loop is placed around the ulnar nerve that is protected throughout the procedure. The cubitodorsal artery is dissected with its veins and subcutaneous tissues distally until it reaches the pisiform. Any other horizontal branches are ligated. The pisiform is then detached from the triquetrum, cutting the capsule between the two bones and taking care to preserve the periosteal arterial circle coming from the cubitodorsal artery. The pisiunciform ligament underneath the ulnar nerve is preserved and harvested with the pisiform. The FCU tendon is detached from the pisiform along with the tissue covering this bone and sutured to the capsule of the triquetrum or the abductor of digiti minimi tendon.

Removing the Lunate

- After retracting the flexor tendons radially, the palmar wrist capsule is exposed. The palmar aspect of the lunate is located at ulnar half of the distal radius: There is almost always a vertical artery visible overlying the capsule of the lunate. This capsule should be opened in a vertical direction and the lunate is exposed. The articular surface of the proximal lunate is palpated. There is usually a depressed zone in the bone or an area of fragmentation. The scapholunate ligament is sectioned near its attachment to the lunate and preserved. The lunate is then removed piece-

meal. A posterior wall of bone may be retained to prevent dorsal dislocation of the transferred pisiform. The luno-triquetral ligament is cut.

Transfer of the Pisiform

- The pisiform bone and its vessels are then transferred to the lunate fossa that is proximal to the position of the pisiform, avoiding traction on this pedicle. The pedicled bone is passed under the FCU tendon and the ulnar nerve, taking care not to twist the pedicle.
- Two K-wires are prepositioned for stabilization of the pisiform. The first is inserted through the triquetrum until it is just visible in the lunate cavity. The second one penetrates the radial aspect of the distal radius at the apex of the anatomical snuffbox, 2 cm proximal to the tip of the radial styloid, avoiding the tendons and the superficial nerves. It is angled in the direction of the lunate fossa until it is seen penetrating the lunate fossa. Alternatively, the second K-wire may be passed through the scaphoid to reach the pisiform.
- Two stitches are passed through the remaining scapholunate ligament. The two stitches are also passed through the pisiunciform ligament. The pedicled pisiform is transferred to the lunate fossa and rotated 90 degrees so that the triquetral facet faces the proximal surface of the capitate. The two stitches are tied while maintaining the pisiform bone in a good position without traction on the pedicle. The two K-wires are then advanced to stabilize the pisiform in position.
- A limited closure of the capsule is performed without compressing the pedicle. An X-ray is done to check the position of the transferred pisiform and its fixation.
- After skin closure, a splint is applied for 3 days followed by a forearm cast for 3 weeks. A soft splint is then applied followed by protected wrist motion. The pins are removed at 6 weeks, and rehabilitation, if necessary, is undertaken.

Combined Procedures

If there is significant discrepancy of the distal radius and ulna, a joint leveling procedure can be performed, usually a radial shortening osteotomy (►Fig. 12) to decrease extracarpal hyperpressure.

In stage IIIb, when there is an increased radioscaphoid angle greater than 60 degrees secondary to palmar flexion of the scaphoid, a limited wrist fusion to reduce the intracarpal hyperpressure may be performed, such as an STT arthrodesis or preferably an SC arthrodesis. Wrist range of motion may be decreased by this procedure. In some rare cases, there were two combined procedures: joint leveling and intracarpal arthrodesis.

Personal Series

Since 1971, I have performed 51 cases. They include 41 men and 10 women who have been operated upon at stage IIIa and IIIb. The maximum follow-up has been 22 years.

Figure 12 Pisiform transfer and radius shortening.

There was an improvement in the pain level by three grades. In range of motion, the average flexion-extension

improved by 35 degrees and radial and ulnar deviation improved by 14 degrees. The strength increased by 10%.

The main advantage of this technique is the gain on pain, which lasts with time.

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