Osteoarthritis of the Wrist and DRUJ

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Alberto Lluch

Keywords
Wrist joint • Distal radio-ulnar joint • Scapho-trapezium-trapezoid joint • Degenerative arthritis • SLAC wrist • SNAC wrist • SMAC wrist • Proximal row carpectomy • Scaphoid resection • Midcarpal fusion • Radio-scapho-lunate arthrodesis • Sauvé-Kapandji procedure

Introduction

In comparison to other joints, such as the spine, hips or knees, primary degenerative arthritis of the wrist is relatively uncommon. Inflammatory arthritis of the wrist is frequently observed in patients suffering from rheumatoid arthritis or crystalline arthropathies. Eventually, crystal deposits in the wrist will lead to degenerative changes. Deposition of urate and calcium pyrophosphate dehydrate (CPPD) material in the synovial tissue are the most common problems affecting the wrist, producing gouty and pseudogout arthritis respectively.

Although primary degenerative arthritis of the wrist is rare, cartilage wear is frequently seen during postmortem examinations of the wrist joints in elderly people. It is not diagnosed radiographically because osteophyte formation is rare in the carpal joints. It is also clinically silent because these patients place less strain on their wrists as they get older, in comparison to weight bearing joints such as the hips and knees.

Degenerative arthritis or arthrosis of the wrist is generally observed around the scaphoid bone. Apart from scapho-trapezium-trapezoid arthritis, as its cause is not yet fully known, the rest are secondary to fractures or subluxations of the scaphoid. The scaphoid bone links the proximal and distal carpal rows, providing stability to the midcarpal joint. When the scapho-lunate ligaments are ruptured or the scaphoid is fractured, joint misalignment will occur, causing wear of the affected joints.

SLAC Wrist

In 1984, Watson and Ballet [1] reviewed more than 4,000 wrist radiographs and found degenerative arthritis in 210 cases (5.25 %), and, in the majority of them, the joints around the scaphoid bone were involved. Most patients presented a pattern of degenerative arthritis from ruptures of

A. Lluch, MD, PhD
Department of Orthopaedic Surgery, Institut Kaplan for Surgery of the Hand and Upper Extremity, Paseo Bonanova, 9, Barcelona 08022, Spain
e-mail: albertolluch@institut-kaplan.com

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the scapho-lunate ligaments and they coined the term "SLAC wrist" [2]. This acronym stands for Scapho-Lunate Advanced Collapse. Four years earlier, Watson and Hempston [2] had already proposed to perform a scapho-trapezium-trapezoid ("triscaphoid joint") arthrodesis for the treatment of "rotary subluxation of the scaphoid".

In the lateral radiographic view of a normal wrist, the scaphoid is seen in about 47° of flexion (ranging from 30° to 60º) in relation to the longitudinal axis of the radius. When grasping objects, the forces transmitted through the distal carpal row will add a flexion torque to the scaphoid. Further flexion of the scaphoid is prevented by its distal ligament insertions to the trapezium and trapezoid and the proximal ligament insertions to the lunate. When the scapho-lunate ligaments are ruptured from injury, flexion of the scaphoid increases, causing a dorsal subluxation of its proximal pole. This type of lesion has been named rotary instability, rotatory instability or flexion instability of the scaphoid. The terms rotary and rotator are not very adequate as they refer to rotation around an axis, which is not this case. Flexion instability of the scaphoid describes the deformity, but scapho-lunate dissociation is probably more appropriate as it defines the lesion better.

In normal circumstances, the lunate is collinear with the radius and the capitate. The normal alignment of the lunate is maintained by the length of the scaphoid and the intact scapho-lunate ligaments, which keeps separated from the radius the distal carpal row. When the scapho-lunate ligaments are ruptured, the scaphoid subluxes dorsally in relation to the radius, and the radial column of the carpus, formed by the trapezium, the trapezoid and the scaphoid becomes shorter. As a consequence, the compression forces through the central column, formed by the capitate and the lunate, will be increased. When the lunate is compressed between the capitate and the radius it always goes into extension. This can be explained because its dorsal horn is thinner than the volar one, and the joint surface of the distal radius is volarly angulated about 11° (Fig. 4.1). The previously described morphology of the distal radius and the lunate explains why it is easier for the lunate to extend rather than flex.

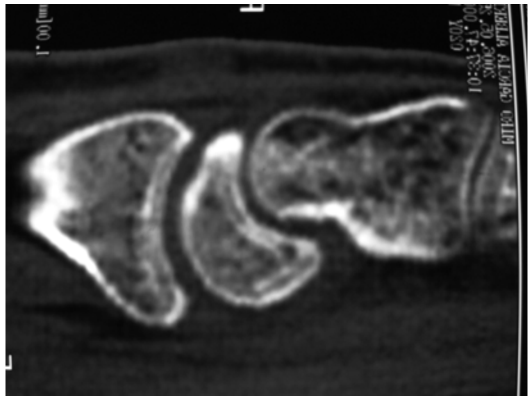


Fig. 4.1 MRI of the central column of a normal carpus in the sagittal plane. Under axial compression, the lunate will always go into extension, due to the volar inclination of the distal radius and the fact that the dorsal horn of the lunate is thinner than the volar one. This will not occur if the scaphoid maintains its normal length and the scapho-lunate ligaments are intact

Consequently, wrist extension takes place primarily at the radio-lunate joint, while flexion is greater at the midcarpal joint [3].

Clinical Diagnosis

Some SLAC wrists are asymptomatic for many years, and the same has been observed for some scaphoid non-unions [4, 5]. In these cases, pain frequently starts after minor trauma, and it is usually localized at the dorsal radio-scaphoid joint. Wrist mobility will be moderately diminished, particularly on extension, as it can only do so at the midcarpal joint, because the radio-lunate joint is already in extension. The arc of wrist flexion is preserved, as both the radio-lunate and the midcarpal joint are able to flex.

Radiological Diagnosis

Originally, the radiographic degenerative changes observed in the SLAC wrist have been classified in three stages, although more recent publications have added two more stages [6, 7]. We, therefore propose a classification in five stages, following a topographical sequence of joint degeneration:

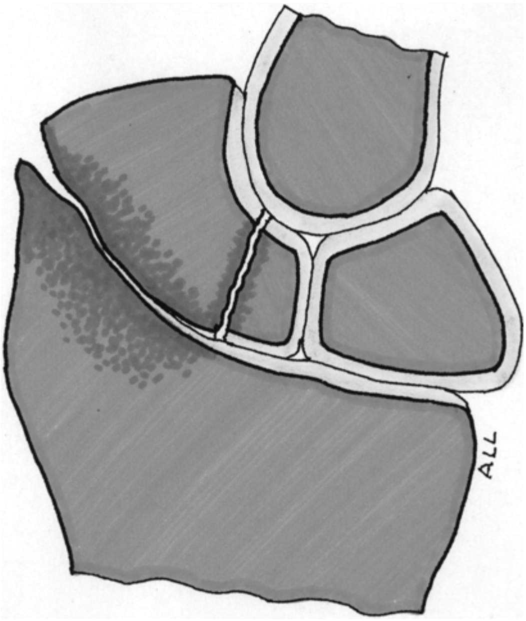


Fig. 4.2 Schematic drawing of a SNAC wrist in stage I. Degenerative arthritis between the radius and the distal fragment of the scaphoid is seen. In cases of SLAC wrist in stage I, the degenerative arthritis will be seen between the radius and the proximal pole of the scaphoid

radio-scaphoid, scapho-capitate, luno-capitate, triqueto-hamate and radio-lunate.

Stage I. The proximal scaphoid is not constraint with the distal radius, has a smaller radius of curvature, and therefore will have a tendency to sublux dorsally when the scapho-lunate ligaments are ruptured. This will cause an increase of its normal flexed position of about 45°. Apart from the increased flexion of the scaphoid, signs of degenerative arthritis will be seen between the radius and the proximal end of the scaphoid, because the area of joint contact will be reduced, causing cartilage wear (Fig. 4.2). In stage I, the radiographic changes at the radio-scaphoid joint will be different in SLAC and SNAC wrists. In SLAC wrists, the proximal scaphoid will be involved, while in SNAC wrist the degenerative arthritis will be most evident at the distal part of the scaphoid, and the proximal scaphoid fragment will be free of degenerative changes. The proximal scaphoid will behave as a lunate, having a similar radius of curvature as that of the radius and following the lunate into extension. The rest of the four stages are quite similar for SLAC, SNAC and SMAC wrists.

Stage II. Arthrosis will progress to the scapho-capitate joint. The joint between the scaphoid and capitate is somewhat cylindrical, and joint incongruence will occur as the scaphoid increases its normal flexed position (Fig. 4.3a, b). Cartilage wear will not be as important as it bears less compressive forces.

Stage III. Because the lunate is in extension, the patient has to flex the wrist at the midcarpal joint in order to keep the hand and fingers aligned with the long axis of the forearm. This causes a dorsal subluxation of the capitates and a reduced contact area between the lunate and the capitate. Joint compression forces are also increased because the scaphoid fails to bear the transmission forces through the radial column of the carpus. Both, the reduced contact area and the increase of compression forces, will cause degenerative arthritis at the luno-capitate joint (Fig. 4.4a–c). The lunate and the radius are very congruent, with their joints having similar radii of curvature, thus radio-lunate arthrosis will be very rare.

Stage IV. This stage is not usually described, but with the passing of time, degenerative changes also occur at the joint between the triquetrum and the hamate bones (Fig. 4.5a–c). Identification of a stage IV SLAC wrist is important for the election of the surgical procedure, as will be discussed later.

Stage V. Degenerative arthritis of the radio-lunate joint was first described by Peterson and Zsabo in 2006 [5]. They named it stage IV SLAC wrist, but we have reserved this stage for the cases with degenerative arthritis of the triquetro-hamate joint, as previously described. Degenerative arthritis is rare at the radio-lunate joint as the articulating bones have a similar radius of curvature and the joint remains congruent even in cases with important extension deformities of the lunate. One possible explanation for the presentation of radio-lunate arthritis is that the lunate goes into extreme extension, most frequently in hyperlax wrists, and gets fixed in this

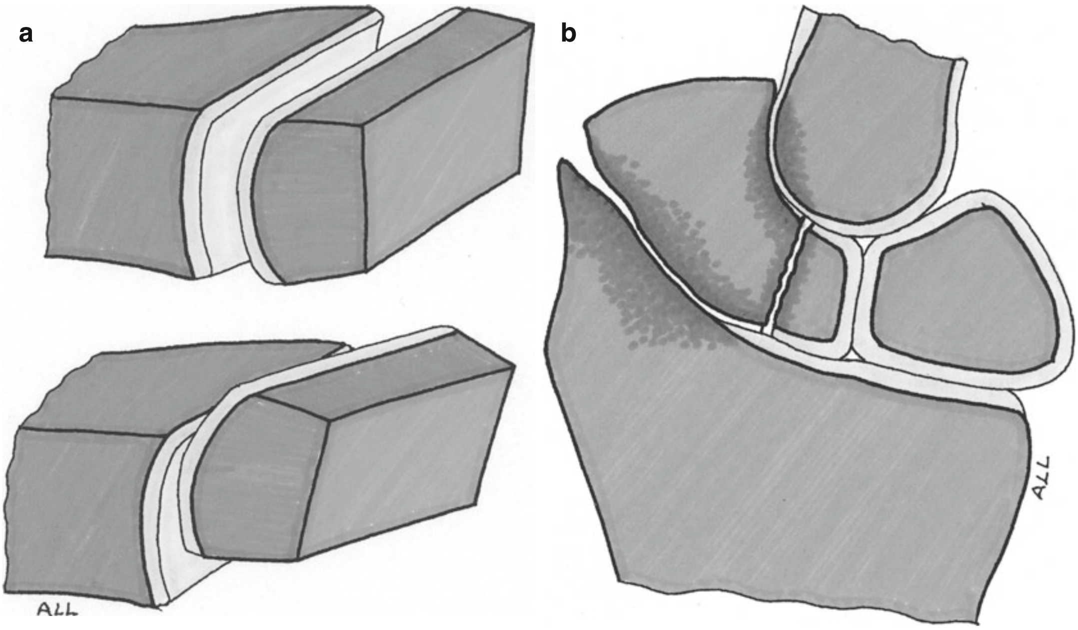
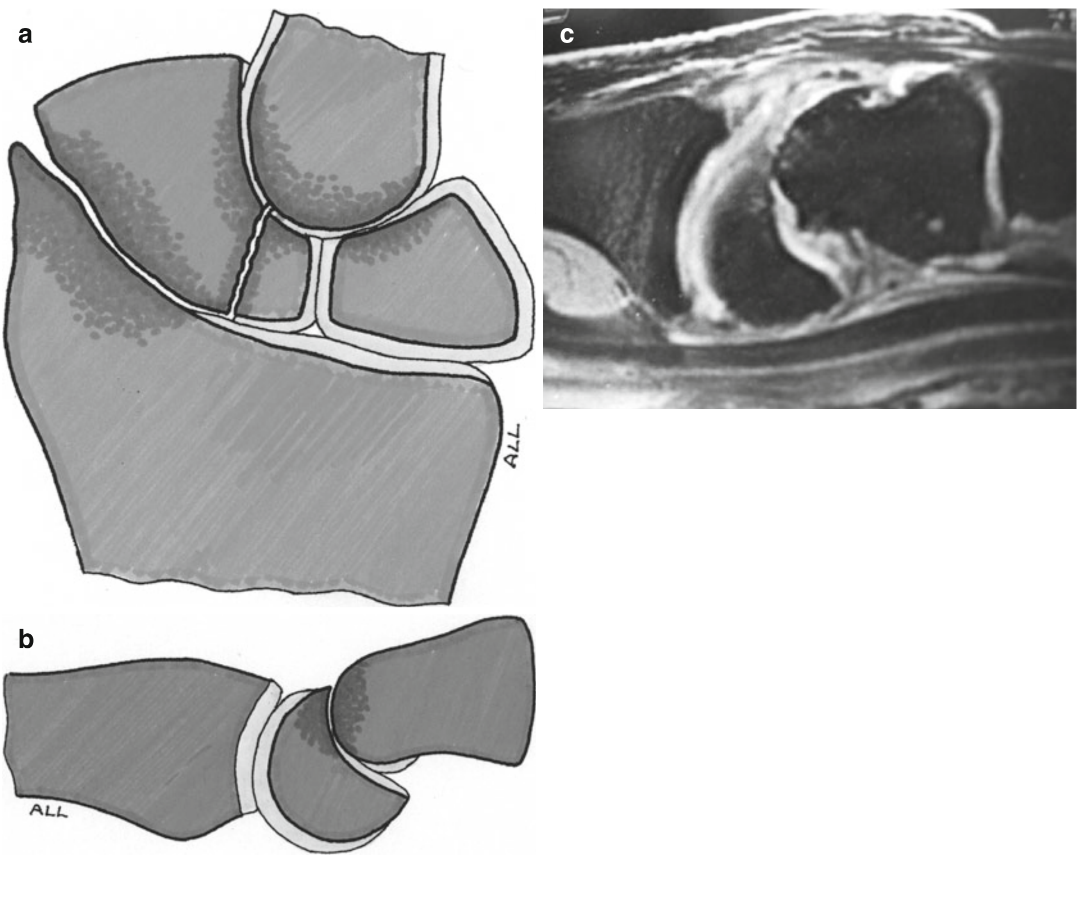


Fig. 4.3 (**a**) Flexion deformity of the scaphoid causes joint incongruence at both the radio-scaphoid and the scapho-capitate joints. (**b**) In stage II SLAC and SNAC wrists, degenerative arthritis between the scaphoid and the capitate is seen



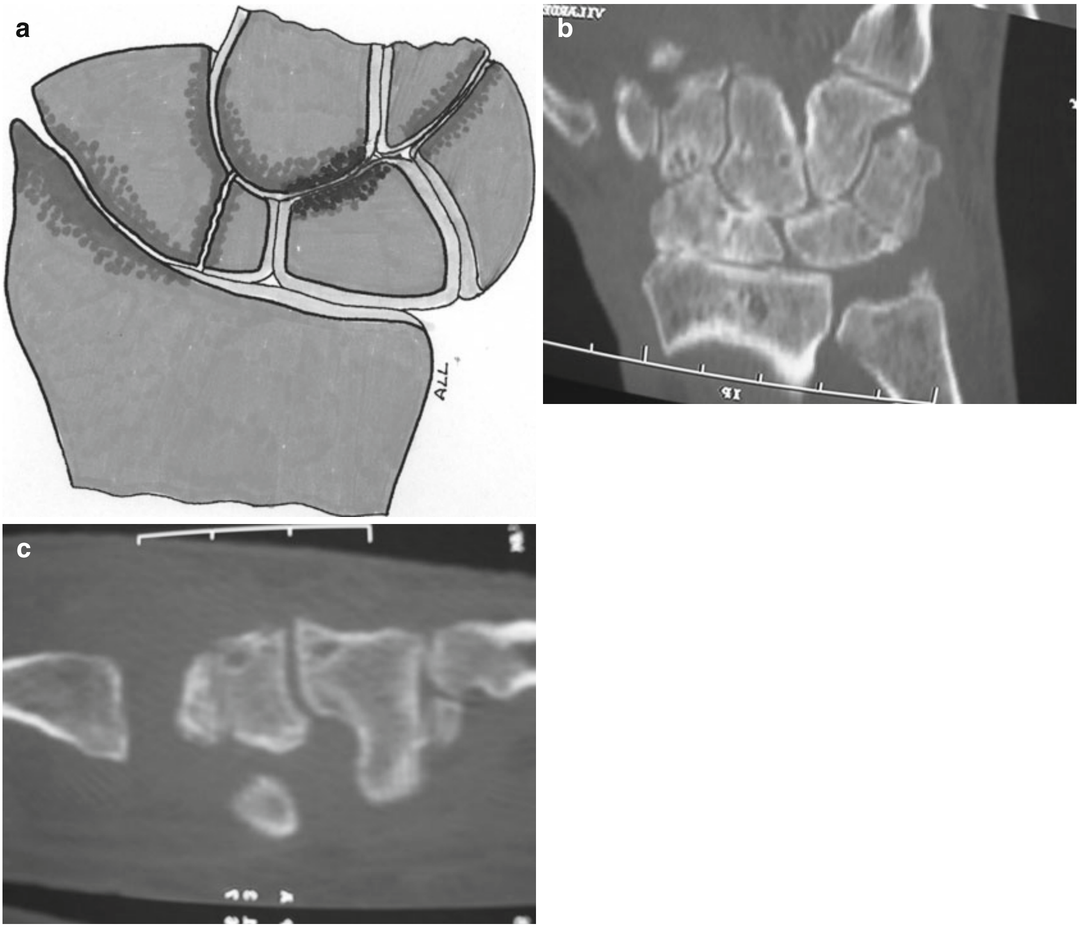


Fig. 4.5 (**a**) In stage IV SLAC and SNAC wrists, degenerative arthritis is also seen between the hamate and the triquetrum. (**b**) Degenerative arthritis between the hamate and triquetrum in the coronal plane. (**c**) Degenerative arthritis between the hamate and triquetrum in the sagittal plane

position, and also pushed down by the head of the capitate, from the very early stages (Fig. 4.6a–c). Since the patient wants to have his hand and fingers aligned with the long axis of the forearm, he has to flex the wrist at the midcarpal joint, which causes dorsal subluxation of the capitate. In case of discomfort, he will bring the wrist in moderate extension, thus reducing the capitate subluxation and changing the contact areas of the joint.

Most times, it is very difficult to make a diagnosis of a stage V SLAC or SNAC wrists from radiographic or MRI examinations. Careful exploration of both joints during the surgical approach will disclose a more severe radio-lunate rather than midcarpal degenerative

Fig. 4.4 (**a**) In stage III SLAC and SNAC wrists, degenerative arthritis will be observed between the capitate and the lunate. (**b**) Extension of the lunate will cause dorsal subluxation of the capitate, causing cartilage wear of the capito-lunate joint. (**c**) MRI of the capito-lunate joint showing synovitis, and degenerative changes in the head of the capitate and dorsal horn of the lunate (Note from the author: please rotate this image horizontally, left to right)

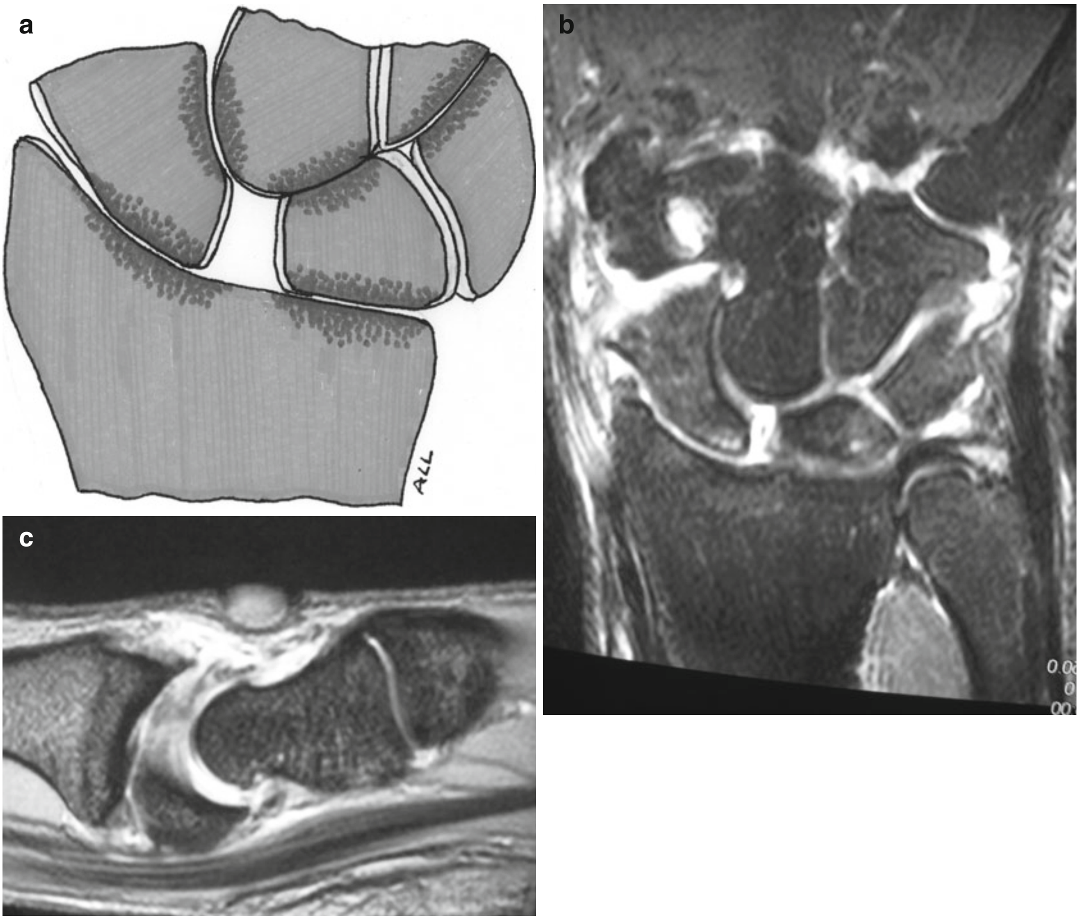


Fig. 4.6 (**a**) In stage V SLAC and SNAC wrists, degenerative arthritis can be observed between the radius and the lunate. (**b**) MRI in the frontal plane of a stage V SLAC wrist in which the midcarpal joint is better preserved than the radio-lunate joint. (**c**) MRI in the sagittal plane showing an important extension deformity of the lunate with alteration of the radio-lunate joint. The midcarpal joint is better preserved as it will become more congruent when the patient extends the wrist

arthritis (Fig. 4.7a, b). After examining 146 wrists with scapho-lunate dissociation, Lane et al. [7] have observed 9 wrists (6 %) with radio-lunate arthritis and no radio-scaphoid and midcarpoal degenerative changes.

SNAC Wrist

In 1970, Fisk [8] first reported degenerative changes after longstanding scaphoid nonunions. These findings were later confirmed by other studies [9, 10]. The pattern of degenerative arthritis is similar to the one described for the SLAC wrist, and for this reason this acronym has been used until recently to describe degenerative arthritis secondary to scaphoid non-union [1]. However, the acronym SNAC wrist, standing for Scaphoid Nonunion Advanced Collapse, seems more appropriate, and its use was suggested by Krakauer et al. [11], even though they continued to use the term SLAC wrist in their own publication. The acronym SNAC is now more commonly used [12, 13].

In the presence of a scaphoid nonunion, the distal fragment flexes from the compression forces transmitted by the distal carpal row. The

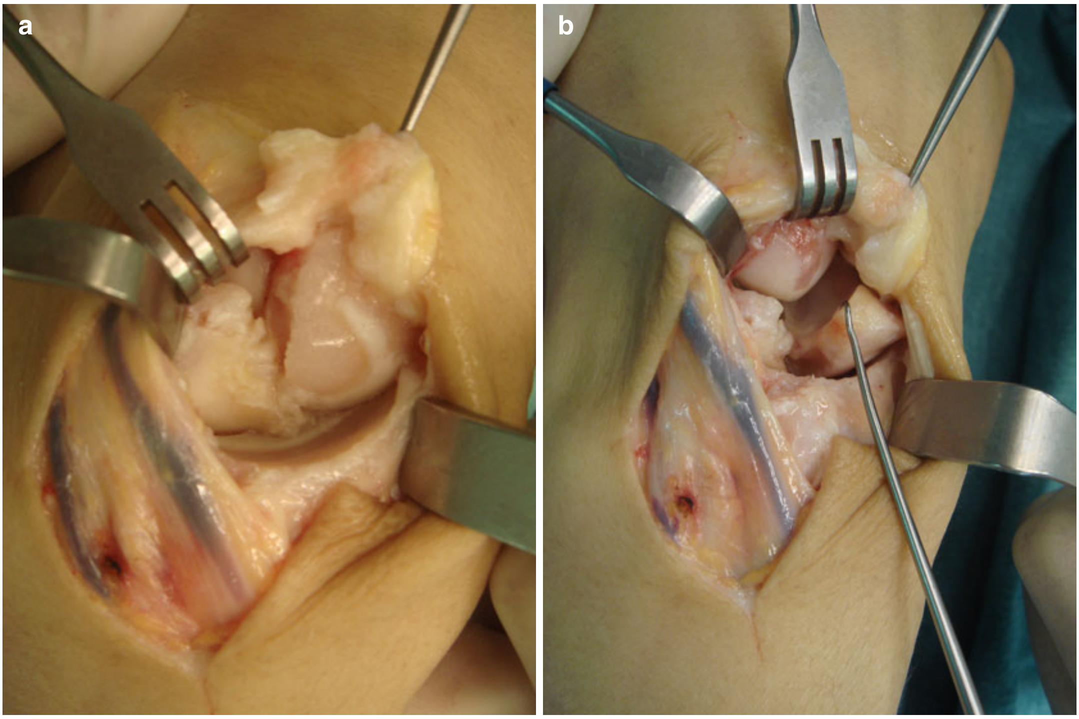


Fig. 4.7 (**a**) Intraoperative photograph of a SLAC wrist showing severe destruction of the proximal joint surfaces of scaphoid and lunate bones. (**b**) The midcarpal joint, particularly the head of the capitate is better preserved

scaphoid also loses its normal length from wear of the bone at the fracture ends. Belsole et al. [14] observed an average of 6–15 % of bone loss (average 10 %) in this bone, which has a volume of 2.3–4 cm^3 (average 3 cm^3). The bone loss is even greater in longstanding cases, as seen in tomographic studies, where the proximal fragment of the scaphoid is barely in contact with the distal radius (Fig. 4.8).

Because the scaphoid is shortened, all compression forces are transmitted by the central column of the carpus, causing extension of the lunate as previously described for the SLAC wrist. The proximal fragment of the scaphoid is brought into extension by the intact scapholunate ligaments [15]. The lunate is very congruent with the radius because their joints have the same radii of curvature. For this reason, perilunate or trans-scapho-perilunate dislocations are more common than pure lunate dislocations. The fact that the lunate is congruent with the radius in all positions of flexion and extension explains why degenerative arthritis between the lunate and the radius does not usually occur even in long standing cases of SLAC or SNAC wrists.

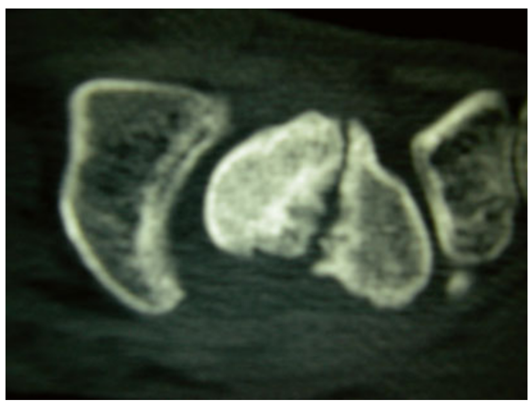


Fig. 4.8 Severe shortening and flexion deformity of the scaphoid after a longstanding pseudoarthrosis. The scaphoid is shortened so much that it barely contacts the radius. The extended lunate brings the proximal fragment of the scaphoid into extension

In the SNAC wrist the proximal fragment of the scaphoid follows the extended position of the lunate and keeps congruency with the distal radius, without causing cartilage wear at this level. The only difference between SLAC and SNAC is in stage I. In the SLAC wrist the degenerative arthritis is seen between the proximal end of the scaphoid and the radius, while in the SNAC wrist, the degenerative arthritis is seen between the distal fragment of the scaphoid and the radial styloid [16].

SMAC Wrist

This acronym proposed by Lluch in 1998 [17] derived from the initial letters of the following words: "Scaphoid Malunion Advanced Collapse". When the scaphoid fracture heals in a deformed position, with shortening, flexion of the distal fragment and extension of the proximal fragment, a pattern of degenerative arthritis similar to the SNAC wrist will also occur [18, 19]. Therefore, the aim of the treatment for scaphoid fractures should not only be to obtain healing, but union of the fracture should be without bone deformity. To prevent a future SMAC wrist pattern of degenerative arthritis, a young patient with a fractured scaphoid which has healed in a very deformed position, should be treated by corrective osteotomy and the addition of an anterior bone graft [20].

The other difference between SLAC, SNAC and SMAC wrists is the time elapsed between the injury and the onset of degenerative arthritis. The SLAC wrist is the one that will progress faster, while the SMAC wrist will take longer to develop degenerative arthritis, and will always have a direct relationship to the degree of scaphoid deformity. Within the SNAC wrists, the worst prognosis will be seen in those cases with a very proximal fracture of the scaphoid, where the distal fragment of scaphoid will very rapidly develop a degenerative arthritis with the radial styloid. When the pseudoarthrosis occurs at the distal end of the scaphoid, the SNAC wrist will take longer to develop.

Clinical Pearls

- SLAC, SNAC and SMAC wrists are patterns of degenerative arthritis secondary to alterations of the scaphoid bone
- SLAC wrist is secondary to scapho-lunate ligament ruptures
- SNAC wrist is secondary to pseudoarthrosis of the scaphoid
- SMAC wrist is secondary to scaphoid malunion
- Radiographic alterations are progressive, and five stages are described
- Radiographic alterations are similar in all of the cases, except for stage I. In SLAC wrists, radio-scaphoid arthrosis is mainly observed at the proximal pole of the scaphoid. In SNAC wrists, the proximal fragment of the scaphoid does not usually develop degenerative arthritis.

Treatment of SLAC, SNAC and SMAC Wrists

When planning for the treatment of SLAC, SNAC or SMAC wrists, standard wrist radiographs will not be sufficient, as it is quite difficult to accurately determine the degree of deformities of the scaphoid and the extended position of the lunate in the lateral projection. Tomographic studies should always be done, which will demonstrate the degree of shortening of the scaphoid, as well as the flexion of the distal fragment and the extension of the proximal fragment [21]. The amount of extension of the lunate can also be measured with precision, as its correction should be the priority of all surgical corrective procedures

Conservative Treatment

Since it is known that some cases of degenerative arthritis are asymptomatic, a trial of conservative treatment is recommended. Apart from the intake of non-steroidal anti-inflammatory medication, the most effective treatment is the immobilization of the wrist with a splint or plaster cast for 3–4 weeks. This proves to be effective in older patients, rather than in younger individuals, and in particular those with a SLAC wrist.

Wrist Denervation

This is a surgical alternative to take into consideration in the older group of patients, because it has the advantages of a shorter postoperative recovery and does not decrease wrist mobility. However, since its effectiveness and duration are limited, it is not a good indication for treating young patients [22, 23].

Radial Styloidectomy

This may be indicated for cases of SNAC or SMAC wrists but not in SLAC wrists. In the latter, a limited dorsal styloidectomy of the radius will alleviate symptoms, but in the long run will cause more instability of the scaphoid, unless the deformity is corrected at the same time. A true radial styloidectomy is a good procedure for the treatment of stages I and II of SNAC wrists, but only when it is associated with the treatment of the nonunion and correction of the deformity by bone grafting of the pseudoarthrosis and internal fixation of the scaphoid. One should be careful not to perform a large styloidectomy, of no more than 6 mm, as there is the danger of causing ulnar translocation of the carpus and radio-carpal incongruence from disruption of the radio-scapho-capitate ligaments [24, 25].

Proximal Row Carpectomy

Proximal row carpectomy can be done in patients with stages I and II, with the advantage of it being an easier procedure than a midcarpal fusion, as it does not require reduction of the lunate deformity, fixation and fusion to the capitate, and no need for possible hardware removal. Postoperative recovery is also faster. Good results have also been reported for the treatment of stage III, when there is minimal wear of the cartilage covering the head of the capitate [26]. However, the good initial results will deteriorate with the passing of time, because the head of the capitate and the distal radius have different radii of curvature. Therefore it is not recommended in patients younger than 35 years of age [27].

Scaphoid Resection and Partial Wrist Fusion

Resection of the scaphoid is the most effective treatment, as pain originated at the radio-scaphoid and scapho-capitate joints will disappear. However, scaphoid excision alone should never be done, as it will cause further collapse of the midcarpal joint, with secondary extension of the lunate. To prevent this, some kind of midcarpal fusion should be associated [28]. The most frequently performed fusion has been called the “four corner fusion”. We do not use this term because we do not fuse corners, but rather bones. A four bone fusion is a more acceptable term but, to be more precise, we prefer to name the bones to be fused.

Watson and Ryu [29] recommended fusing the capitate and hamate to the lunate and triquetrum. At first, they replaced the scaphoid with a silicone implant, which was later abandoned because of frequent implant dislodgement and occasional foreign body reaction to silicone particles. Internal fixation can be achieved with transosseous K-wires, compression staples, headless compression screws or circular plates.

The skin incision at the dorsum of the wrist can be longitudinal, transverse or zig-zag. A longitudinal incision seems to be favored by most surgeons as it decreases the chances of injury to the venous return and the branches of the sensory radial nerve. However, it will require more retraction of the skin edges and increased soft tissue damage. A dorsal transverse incision will provide adequate visualization of the carpal bones, as the skin is very mobile in this area. This is the recommended incision for women with smaller size wrists, because of its superior aesthetic result. In the case of large hands, usually in men, a zigzag incision is recommended as it provides a better

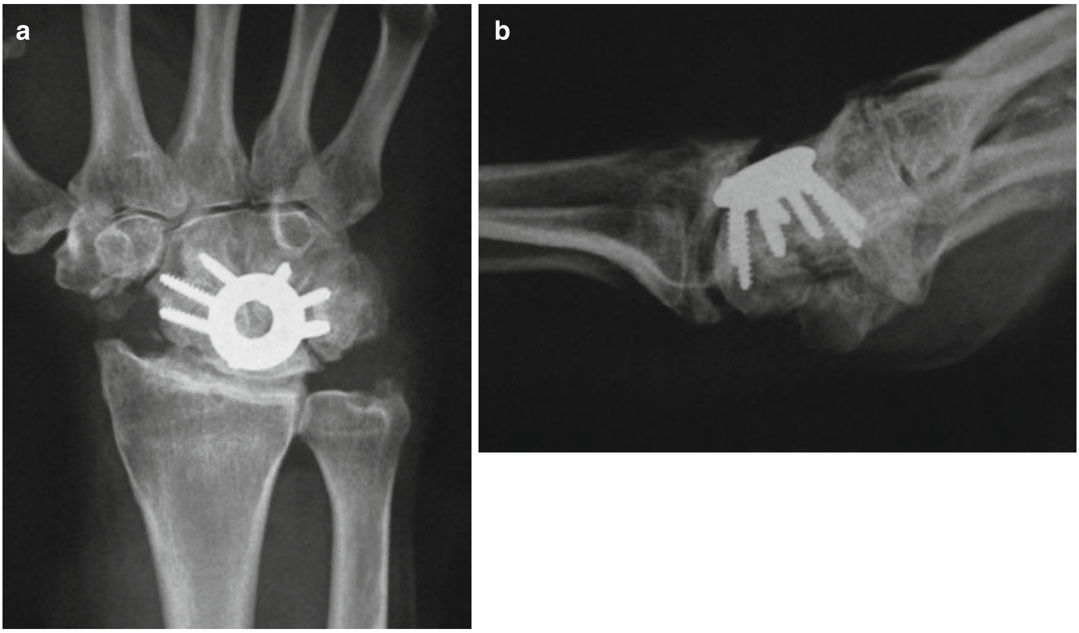


Fig. 4.9 (**a**) Scaphoid excision and midcarpal fusion for the treatment of a SNAC wrist stage IV. A *Spider* ® circular plate has been used for internal fixation of capitate, lunate, hamate and triquetrum bones. (**b**) Same *Spider* ® plate in the lateral x-ray projection. Because the plate was too superficially placed over the carpal bones, it caused impingement with the radius on wrist extension

exposure. The middle part of the zigzag goes in an oblique direction, following the 23° inclination towards the ulnar side of the distal end of the radius. The incision is extended proximally and distally at 90° angles. This will provide the best exposure by gently retracting the proximal and distal flaps to the sides, without any traction to the skin edges. The surgical scar will also be less noticeable than using a longitudinal incision. Next, the capsule is divided from the distal end of the radius, being careful not to divide the dorsal radio-triquetral ligament at the most ulnar side of the radius. This will provide excellent exposure of the radio-carpal and midcarpal joints. After the midcarpal joint is identified, a 2–2.5 mm K-wire is inserted at the dorsal horn of the lunate. The direction of the wire should be from posterior to anterior and from proximal to distal, so the lunate is transfixed perpendicularly from the posterior to the anterior horn. Fluoroscopic examination should be done to confirm the correct position of the K-wire, as it should not go through the midcarpal joint or protrude anteriorly outside the lunate. Using the K-wire as a lever arm, the lunate is brought into neutral position by pushing the K-wire distally. More or less force will be required depending on the duration and the degree of deformity, which will have caused remodeling of the anterior capsular structures of the midcarpal joint. As mentioned before, a K-wire protruding anteriorly on the lunate will impinge on the anterior border of the distal radius, causing difficulties for a complete reduction. Correction of lunate extension will be easier if the scaphoid is removed first. This can be done with just a bone rongeur, but excision of the distal scaphoid will be difficult, and a scalpel will be needed to divide the scapho-trapezium-trapezoid ligaments. To obviate this, the distal scaphoid does not need to be removed, as it will not cause any impingement with the distal radius during radial inclination of the wrist, as it is located in a plane anterior to the distal radius (Fig. 4.9a, b).

Due to its convexity, excision of the subchondral bone of the head of the capitate can be done easily with a rongeur. However, excision of the subchondral bone of the lunate, because of its concavity, will be more difficult with a rongeur,

Fig. 4.10 Capito-lunate fusion for the treatment of a SLAC wrist. Internal fixation was achieved with two parallel headless compression screws. The distal scaphoid does not need to be removed, as it is located anterior to the radius and will not cause impingement during radial inclination of the wrist

particularly in those cases with sclerotic subchondral bone. The intermittent use of a small bone curette will facilitate this task. After the subchondral bone of the capitate and lunate are removed, correction of the extension of the lunate should be done with the K-wire used as a lever arm. If a complete midcarpal fusion is intended, the subchondral bone of the hamate and triquetrum should also be removed. This should always be done in stages IV of degenerative arthritis. In the other cases, we prefer to fuse only the capito-lunate joint (Fig. 4.10). Fusion of the hamate and triquetrum may cause ulno-carpal impingement in those patients with an ulna which is of equal length or longer than the radius, as the fused triquetrum will not be able to move distally during ulnar inclination of the wrist. To prevent this, some surgeons also recommend excising the triquetrum.

Internal fixation of the midcarpal joint, either partial (luno-capitate) or total (luno-capitate and triquetrum-hamate) can be done with K-wires, although this can be quite difficult, as they must be inserted from distal to proximal and follow the longitudinal axis of the carpus. To prevent impingement of the wires with the radius, another possibility is to place the wires transversely from the ulnar side of the wrist. Internal fixation can also be accomplished with a circular plate and screws: *Spider plate ® (Kineticos Medical, Inc.)* (Fig. 4.9a, b). A *Diamond Carpal fusion plate ® (Small Bone Innovations, Inc.)* with 4 screws has also been designed for internal fixation of a midcarpal fusion. The Spider plate has the advantage of facilitating the technique of denuding the subchondral bone with a specially designed Spider rasp and the placing of 6–8 screws, depending on which size plate is being used for the arthrodesis. A possible complication is impingement of the plate against the distal end of the radius, during extension of the wrist, when it is placed too superficial over the carpal bones to be fused (Fig. 4.9b). Care should be taken that the screw for the triquetrum is not too long, because it will transfix of the piso-triquetral joint. Another inconvenience, not really related to the design of the plate, is that this technique makes the surgery too easy, and the less experienced surgeon may not really perform and adequate removal of all the subchondral bone of the capitate, lunate, triquetrum and hamate, causing non-union of some of the joints. Vance et al. [30] reported more complications with the use of a circular plate versus traditional techniques.

Total midcarpal fusion, including capitate, hamate, lunate and triquetrum, will prevent the normal distal displacement of the triquetrum during ulnar inclination of the wrist. As a consequence, ulno-carpal impaction may occur in cases where the ulna is of equal length or longer than the radius. To prevent this, some authors recommend to perform only a capito-lunate arthrodesis, with [31, 32] or without excision of the triquetrum [33].

We obtained the best results by only fusing the capito-lunate joint, after excision of the scaphoid and correction of lunate extension. Internal fixation is accomplished with two parallel cannulated headless screws of 2 mm diameter introduced from the proximal joint of the lunate into the capitate (Fig. 4.10). Dimitrios et al. [34] obtained a 100 % union rate of capito-lunate fusions, but 3 out 8 patients still had persistent pain. The pain, most probably originated at the triquetral-hamate joint in cases of stage IV degenerative wrist. To prevent this possible complication we recommend a total midcarpal fusion only in cases of stage IV degenerative wrist.

Another subject that needs to be discussed is what to do with the proximal pole of the scaphoid in cases of SNAC or SMAC wrist. In such cases, the proximal pole of the scaphoid behaves as the lunate, placing itself in extension without causing degenerative arthritis with the radius. For this reason, the proximal pole of the scaphoid should be left in place, for the purpose of increasing the surface of joint contact between the carpal bones and the radius, particularly when the lunate is not fully covered by the radius. The proximal pole of the scaphoid can be left intact, after its correction together with the lunate, or can be fused to the capitate as proposed by Viegas [35].

Radio-scapho-lunate Arthrodesis

This would be the preferred technique for cases of stage V arthritis (Fig. 4.11), as mobility at the midcarpal joint will be preserved. The so called "dart throwers motion" (DTM), which follows a plane that varies from 37° to 59° from the sagittal plane according to the different investigators [36–38] takes place at the midcarpal joint. This is the plane followed by the wrist extensors, extensor carpi radialis longus and brevis, and the main wrist flexor, the flexor carpi ulnaris, and used for the majority of hand activities. Patients prefer and adapt quicker to a radio-scapho-lunate arthrodesis than a midcarpal fusion. Excision of the distal scaphoid increases mobility after radio-scapho-lunate arthrodesis [39].

Fig. 4.11 A stage V SLAC wrist has been treated by means of a radio-scapho-lunate fusion

Total Wrist Fusion

Since scaphoid excision and partial or total midcarpal arthrodesis provide good results, the indications for a total wrist fusion are limited. This is due to the fact that the radio-lunate joint maintains its integrity, even in longstanding cases, except for the rare stage V degenerative arthritis.

Total Wrist Arthroplasty

A flexible silicone wrist implant was designed by Swanson in 1973 [40]. It was mainly intended for use in rheumatoid patients. Early results were generally gratifying, with good pain relief and an acceptable range of motion. However, longer follow-up revealed subsidence within the distal carpal row and rupture of the implant in the majority of cases [41, 42]. Foreign body reaction to silicone particles had a lower incidence as compared to scaphoid or lunate implants.

The first designs of rigid two component implants also presented an unacceptable complication rate, and consequently most are no longer in use, except for low demand rheumatoid patients. However, in the past several years substantial design modifications have been introduced. The distal bone anchorage is not into the metacarpals but into the distal carpal row by means of an elliptical metallic plate and screws [43]. The *"Universal Total Wrist"* ® implant was

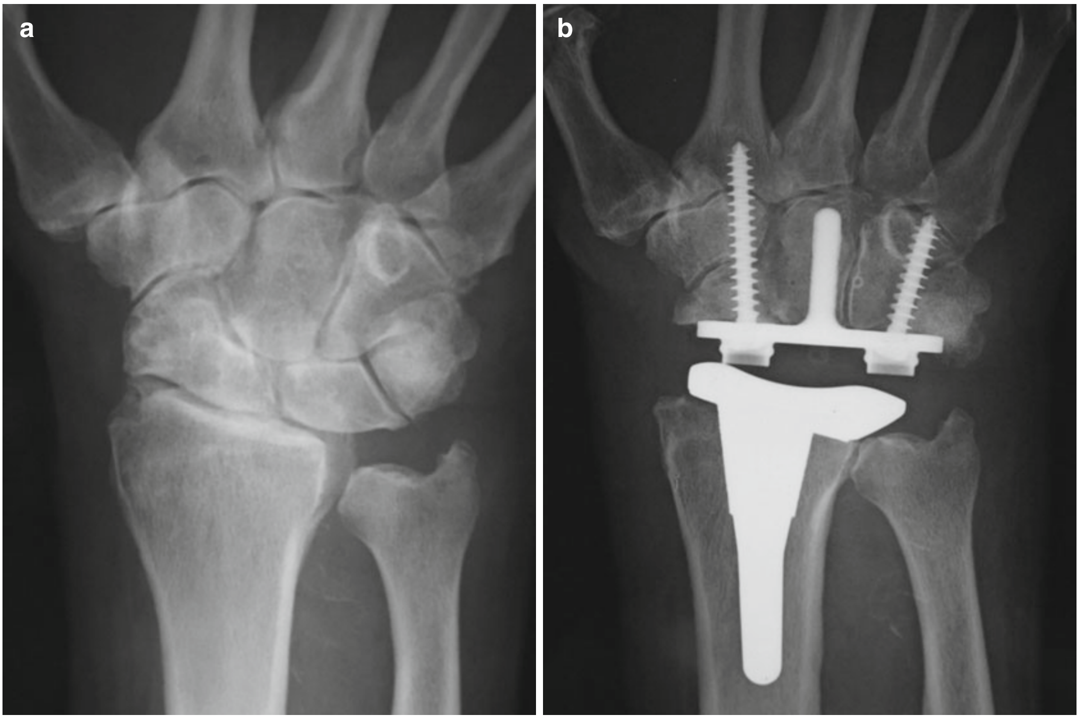


Fig. 4.12 (**a**) SMAC wrist stage IV with degenerative changes between the radius and the scaphoid, and the entire midcarpal joint. A volar approach to the scaphoid and a radial styloidectomy had been undertaken many years ago, causing a moderate ulnar translocation of the carpus. (**b**) As there was little contact between the radius and the lunate, a wrist replacement using a *Universal Total Wrist II* ® was performed, with very satisfactory results

manufactured by *Kineticos Medical Inc. San Diego CAL. USA*. Since the anchorage should be in the distal carpal row, these bones should be well preserved, or fused in cases of rheumatoid arthritis [34]. These total wrist implants are semi-constrained, with the polyethylene bearing between both components having a condylar shape, which has recently changed from toroid to ellipsoid to improve stability and decrease wear [44, 45]. After some modifications from the original design, this new implant is known as *"Universal Total Wrist II ® (Integra LifeSciences, Plainsboro, NJ, USA).*

Although initially used for the treatment of rheumatoid arthritis, these new implants, also called third generation, have also been used for the treatment of degenerative arthritis with short term satisfactory results. We have offered this alternative to patients who require painless wrist mobility for certain activities of daily living or, even more important, for work requirements. The patient should be willing to accept possible future complications, such as implant loosening or wear. In our experience the midterm clinical and radiographical results have been very satisfactory [46] (Fig. 4.12a, b).

Other third generation total wrist implants are the *Re-motion ® (Small Bone Innovations, Morrisville, PA, USA)* [47] and the *Maestro ® (Biomet Orthopedics, Warsaw, IN. USA)* [48].

Clinical Pearls

The most important surgical procedure consists of removing the scaphoid

The midcarpal joint should be fused after correcting the extension deformity of the lunate

A luno-capitate arthrodesis will provide equal results to a four-bone fusion

Proximal row carpectomy is another surgical alternative when the head of the capitate is not involved.

Scapho-trapezio-trapezoid (STT) Arthritis

Incidence

The first description of S-T-T arthritis was made by Carstam et al. in 1968 [49]. Since then, the incidence of degenerative arthritis of the S-T-T joint, based on radiographic examinations, has been reported from 7 to 55 % [50–55]. As in all degenerative arthritis in the wrist, the incidence is much higher if the diagnosis is done by anatomical dissection of the wrist of elderly people. Bathia et al. [55] examined 73 cadaveric wrists, 25 male and 48 female, with an average age of 84 years, and found an incidence of 83.3 %. Degeneration of the scapho-trapezoid articular surface was found to be more common and severe than that of the scapho-trapezium joint.

Etiopathogenesis

Some authors think that S-T-T arthritis and S-L dissociation may be related [56]. Weinzeig and Watson [57] observed a SLAC pattern of degenerative changes in 57 % of the cases of periescaphoid arthritis, 27 % of arthritis only at the S-T-T joint, and a combination of both in 15 % of the cases. However, careful observation of the lateral radiographs of SLAC and SNAC wrists demonstrate opposite deformities of the scaphoid. In cases of S-L dissociation, the scaphoid is flexed and the trapezium and trapezoid are frequently found to rest on the dorsal nonarticular portion of the distal scaphoid. On the contrary, in the presence of S-T-T arthritis, the scaphoid is usually extended. Simultaneous observation of S-L dissociation and S-T-T arthritis (15 %) in the same patient could only be considered a coincidence.

The progression of scapho-trapezial ligament injuries to S-T-T osteoarthritis was first suggested by Taleisnik [58]. Linscheid et al. [59] reported that 16 of their 38 patients with isolated S-T-T osteoarthritis had previously sustained injuries to the thumb column. Sicre et al. [60] also observed osteoarthritis of the S-T-T joint after scapho-trapezial ligament injuries, and we also have seen the same finding. Taleisnik [58] believes that the development of osteoarthritis of the S-T-T joint may, in many patients, be the result of an unstable S-T-T articulation. This concept should be taken into consideration, as most S-T-T arthroses are seen in women, who also have a higher predisposition than men to develop both T-MC and interphalangeal arthritis secondary to joint instability.

Pinto et al. [61] reported a 48 year old man with S-T-T osteoarthritis secondary to a well documented nontraumatic multidirectional instability of the S-T-T joint. However, not all authors are clear as to which came first: joint instability or joint arthritis [62].

MClean et al. [63] found an association between S-T-T arthritis and lunate morphology. They evaluated 48 patients with S-T-T arthritis, and found that 83 % of them had a lunate type II, while in the control group this was only present in 64 % of the wrists. Lunate type II is defined as that which has two distinct distal facet joints, one for the capitate and the other for the hamate [64]. They postulate that lunate morphology is associated with variations in scaphoid motion, and that these differences may contribute to the development of S-T-T osteoarthritis. We reviewed 27 cases of S-T-T osteoarthritis and found that the majority of patients had a lunate type I. As the authors conclude in their manuscript, further research is required to investigate the relationship between midcarpal morphology and carpal kinematics.

We have observed that chondrocalcinosis or pseudogout, caused by deposition of crystals of Calcium Pyrophosphate Dihydrate (CPDD), is another cause of S-T-T arthritis, all of them confirmed by pathological examination with polarizing light.

Clinical Diagnosis

The onset of symptoms is usually insidious and slowly progressive, although it can be precipitated by an injury such as a fall on the outstretched hand. Radiographic examination done at the time of consultation will already show degenerative arthritis, proving that this may have remained asymptomatic for a long period of time. Such is the case that arthritis can be a radiographic finding during an examination done for other purposes.

The patient complaints of pain and weakness during forceful use of the thumb. Decreased wrist mobility is also a common finding, because mobility at the midcarpal joint will be restricted, although the patient may not have been aware of this previously. Differential diagnosis should be done between trapezio-metacarpal arthritis and De Quervain tenosynovitis. This should not be very difficult, as the patient will have pain on direct pressure over the S-T-T joint, volarly, radially and dorsally. Dorsal swelling from joint synovitis can be seen on the dorsal and radial aspect of the wrist.

Some patients may have more pain at the radio-volar aspect of the wrist, from synovitis of the flexor carpi radialis (FCR) tendon or ganglia originating from the scapho-trapezial capsule and migrating proximally along the tendon sheath [65]. The FCR tendon courses over the volar surfaces of the scaphoid and trapezium in a separate fibro-osseous tunnel. MRI studies in patients with S-T-T arthritis demonstrated synovitis of the FCR, partial and full thickness tears and ganglion formation.

An intra-articular infiltration with a local anesthetic will cause immediate temporary relief of pain, confirming the diagnosis.

Radiographic Diagnosis

Due to bony overlap, it is difficult to view the STT joints using standard radiographs. The best way to see the S-T-T joint is by placing the wrist in 30° of ulnar inclination so that the thumb is fully extended and in a straight line with the forearm. The thumb pulp is facing and touching the cassette while the hand and forearm are lifted from the cassette forming an angle of about 30°. The x-ray beam is centered at the S-T-T joint, with the x-rays crossing perpendicular to the joint line [66].

Joint space narrowing, subchondral bone sclerosis, and peripheral hyperthrophic spurring will be observed. Subchondral bone cysts are rare. The most interesting finding is an extension deformity of the scaphoid, best seen on lateral radiographs. In the lateral x-ray projection, the normal radio-scaphoid angle, varies between 45° and 60°, and in advanced cases of S-T-T arthritis we can see angles of 20° or even less. We believe that the extension deformity of the scaphoid is due to shortening from wear of the cartilage and the bone ends, as seen in other joints, such as the T-MC, hip or knee joints (Fig. 4.13). Furthermore, the extension of the scaphoid appears to be progressive with increasing joint space narrowing. Another factor is the presence of a moderate dorsal subluxation of the distal scaphoid, although, this could be secondary to the latter. Since the radial column of the carpus is shortened, the scaphoid will not be able to maintain the length of the central column, which will progressively collapse [67]. The wedge shaped lunate, with a dorsal horn thinner than the anterior horn, interposed between the capitate and the radius, will be pushed into extension. The normal 11° volar inclination of the distal radius will facilitate the extension of the lunate (Fig. 4.1).

Fig. 4.13 S-T-T degenerative arthritis with shortening of the scaphoid secondary to cartilage and bone wear. The scaphoid and the lunate are in an extended position

Clinical Pearls

S-T-T ostheoarthritis is the most frequent primary arthritis of the wrist

The proximal carpal row becomes progressively extended

Extension of the lunate will cause dorsal subluxation of the capitate.

Treatment

Conservative

As many cases of S-T-T arthritis remain asymptomatic for several years, a trial of conservative treatment is recommended. Apart from the intake of non-steroidal anti-inflammatory medication, the most effective treatment is the immobilization of the wrist with a splint or plaster cast for 3–4 weeks. Intra-articular steroid injections will enhance the results of the conservative treatment. This can be effective in older patients, but not so much in younger individuals.

Flexor Carpi Radialis Tendon Release and Joint Debridement

In some patients, the discomfort caused by flexor carpi radialis tenosynovitis is more important than that caused by the arthrosis. In these cases, through a volar zig-zag surgical approach, the FCR tendon is released and synovectomy performed. Prominent anterior osteophytes, originating at the scapho-trapezoid joint, should also be removed, as these will cause tendon synovitis, tendon attrition and even rupture in some cases.

Arthroscopic debridement has also been described [68]. The authors performed a washout of the joint with arthroscopic debridement of the hyperthrophic synovial tissue, chondral flaps and osteophytes, reporting satisfactory results on an average of 36 months of follow-up.

Resection of the Distal Scaphoid

As in many other joints of the hand a resection arthroplasty will provide excellent results. The distal pole of the scaphoid can be removed through a dorso-radial zigzag incision or with a volar approach in those cases presenting with FCR tenosynovitis. Crosby et al. [69] recommended to interpose a slip of the FCR in a coiled fashion.

Although excision of the distal scaphoid will provide satisfactory results, it will cause further midcarpal instability in some cases [70]. It may be well tolerated in some of them, but others will require a capito-lunate arthrodesis after correcting the extension of the lunate. To prevent midcarpal subluxation after distal scaphoid excision, Garcia-Elias and Lluch [71] proposed a dorsal capsulodesis of the scapho-trapezoid joint with a distally based capsular flap tightly reattached on to the dorsum of the scaphoid. It is recommended that before proposing a resection of the distal scaphoid a dorsal midcarpal instability should be ruled out under fluoroscopic control. If a “posterior drawer sign” of the midcarpal joint is clearly demonstrated, then an S-T-T arthrodesis would probably be a better treatment option [72].

Trapezium Silicone Implant Arthroplasty

Removal of the trapezium and replacement with a silicone implant will provide satisfactory results when the main arthrosis is present at the T-MC joint [73]. Implant arthroplasty will alleviate pain from the trapezio-metacarpal and the scapho-trapezium arthritis, as both joints are treated by replacement of the trapezium with the implant. Pain from the scapho-trapezoid joint is also relieved from the joint distraction effect provided by the implant (Fig. 4.14a, b). The implant will prevent further erosion of the trapezium and scaphoid, with secondary shortening and extension deformity of the latter. A subluxation of the implant is a major concern, but it can be prevented by using a careful surgical technique.

Pyrocarbon Implant Interposition

After excision of the distal scaphoid, Pequinot [74] proposed to interpose a disc made of pyrocarbon between the scaphoid and the trapezium called “*STPI implant*” ®, standing for Scaphoid Trapezium Interposition Implant, *BIOProfile, Grenoble, France*. This disc provides

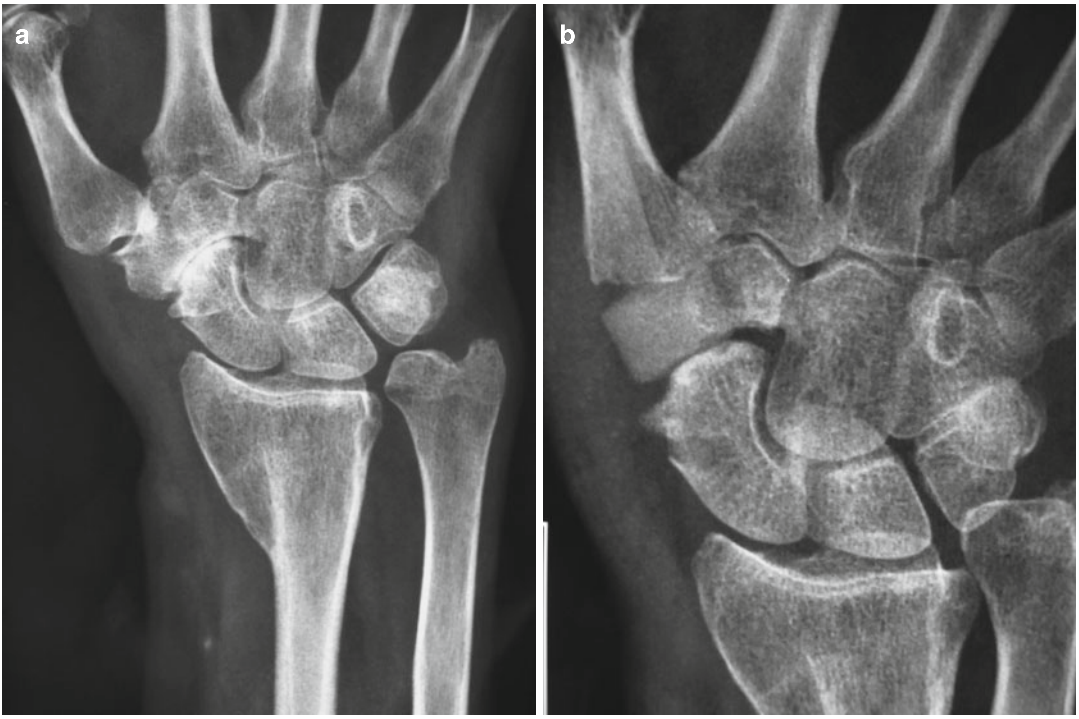


Fig. 4.14 (**a**) Degenerative arthritis of the T-MC and S-T-T joints in an elderly woman who had previously suffered a fracture of the distal radial metaphysis. In spite of the deformity, the distal radio-ulnar joint was painless and she had full pronation and supination of the forearm. (**b**) The arthritis of the T-MC and S-T-T joints was treated with a trapezium silicone implant. The implant restored the length of the radial column of the carpus, preventing collapse of the central column and alleviating pain at the scapho-trapezoid joint

a satisfactory relief of symptoms and an increase in grip strength, but postoperative dislodgement of the implant is a possible complication: 20 % in the first reported series of cases.

Arthrodesis of the Scapho-trapezio-trapezoid Joints

Arthrodesis of the S-T-T joints was first done by Watson in 1980 [2]. In 2003 they reported the results of a follow-up study on 800 S-T-T fusions, mostly done for the treatment of scapho-lunate dislocations. The results were uniformly good except for the risk of developing radio-scaphoid degenerative arthritis with the passing of time [75]. S-T-T fusion restricts scaphoid flexion, mainly during radial inclination of the wrist causing radio-scaphoid impingement. For this reason it is contraindicated in cases with preexisting degenerative changes of the radio-scaphoid joint. Radio-scaphoid arthrosis after S-T-T fusion has also been reported by other authors [76]. To prevent this, they recommended to arthrodese the distal scaphoid at 58° of flexion. Minamikawa et al. [77] recommended performing the S-T-T fusion with a radio-scaphoid angle from 41° to 60°. The purpose is to fuse the scaphoid in a slightly more flexed position than normal, in order to prevent radio-scaphoid impaction during wrist mobility.

The arthrodesis can be done trough a dorso-radial transverse or zigzag incision. The S-T-T joint is quite large, and careful removal of all the cartilage and subchondral bone should be performed so as to avoid nonunions. Internal fixation can be done with Kirschner wires, although headless cannulated screws will provide compression and better stability of the bones to be fused (Fig. 4.15a, b).

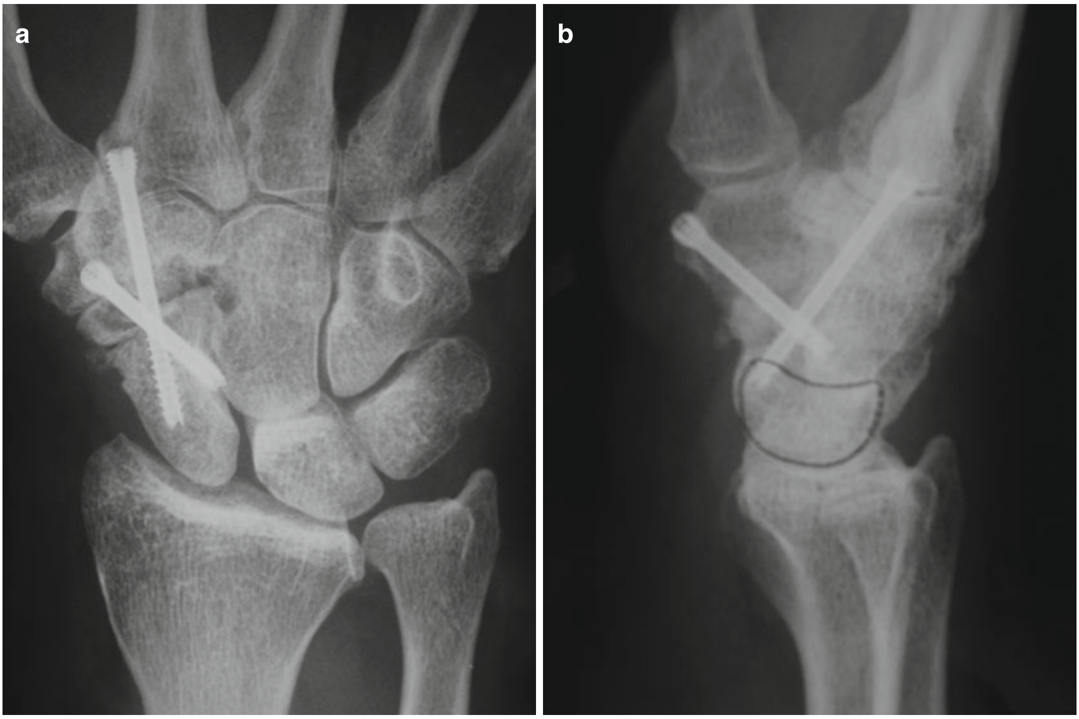


Fig. 4.15 (**a**) AP radiograph of an S-T-T arthrodesis with the interposition of a bone graft to correct the extension deformity of the scaphoid and regain length of the radial column of the carpus. The arthrodesis was stabilized with two headless compression screws, from the trapezium and the trapezoid into the scaphoid. (**b**) Lateral radiograph of the S-T-T arthrodesis demonstrating the correction of the extension deformity of the lunate. The pisiform was used as a bone graft as the patient also had important severe pain from a piso-triquetral degenerative arthritis

The most difficult deformity to be treated is the extension deformity of the scaphoid causing dorsal subluxation of the midcarpal joint. If the scaphoid position is not corrected, the patient will continue to have pain at the luno-capitate joint, and luno-capitate fusion may be needed in the future. Since our aim is to reduce the extension of the lunate, after denuding the S-T-T joint, we correct the lunate extension with a K-wire, using it as a lever arm, the same technique that is used for the SLAC and SNAC wrists. Next, the gap at the S-T-T joint is filled with a cortico-cancellous bone graft obtained from the distal radial metaphysis.

Radio-lunate Arthrodesis

Excision of the distal scaphoid will cause dorsal subluxation of the capitate, mainly in patients with hyperlax wrists, causing degenerative arthritis and pain at the luno-capitate joint. S-T-T arthrodesis after correction of the extension deformity of the scaphoid will prevent midcarpal joint collapse, but the surgical technique is quite demanding as it is difficult to regain scaphoid length without the use of a large bone graft.

Recently we have treated S-T-T arthritis with a radio-lunate arthrodesis after correcting the extension deformity of the lunate. With this procedure the midcarpal collapse is corrected and future osteoarthritis at this level is prevented. Simultaneous excision of the distal scaphoid will alleviate symptoms at the S-T-T joint. In other cases, we have performed a FCR tendon release and a circumferential capsulotomy between the scaphoid and the trapezium and trapezoid bones through an anterior approach with equally satisfactory results.

Clinical Pearls

- Several treatment options have been proposed: conservative, FCR tendon release, resection of the distal scaphoid, trapezium silicone implant arthroplasty and arthrodesis
- Resection of the distal scaphoid should not be done in patients with laxity of the midcarpal joint, as dorsal subluxation of the capitate will increase
- Radio-lunate arthrodesis is a newly proposed technique.

Distal Radio-Ulnar Joint (DRUJ) Degenerative Arthritis

Primary degenerative arthritis is rare, but secondary arthritis will occur from joint cartilage destruction after fractures of the distal radius or ulna. Other causes are joint in congruencies secondary to joint instability or length discrepancies between the radius and ulna, usually occurring after malunited fractures of the distal radius.

The anatomy of the radio-carpal joint varies very little among the different individuals, with the joint facet of the distal radius presenting an almost constant ulnar inclination of 23° and a volar inclination of 11°. However, the filogenesis of the human DRUJ explains the wide variety of morphological changes observed among different individuals. We may see different sizes of the head and styloid process of the ulna, as well as a joint with a variety of sizes and inclinations. For this reason, the length of the ulna in relation to the radius is not constant, with some individuals having a shorter ulna with a joint with an inclination following a plane from proximal-radial to distal-ulnar. The only anatomical feature constant in everyone is the radius of curvature of the sigmoid notch of the radius being larger than that of the head of the ulna, which does not make the DRUJ a fully constrained joint. The head of the ulna has a slight proximal displacement on pronation of the forearm, and a larger antero-posterior displacement during forearm rotation. The different radii of curvature allows for the ulnar head to displace anteriorly during forearm supination, and dorsally, in reference to the radius, on full pronation of the forearm [78].

Diagnosis

Patients with degenerative arthritis of the DRUJ complain of pain on the ulnar side of the wrist on pronation and supination of the forearm, mainly during load bearing. Pain is usually more severe during forearm supination, due to the anterior displacement of the head of the ulna which causes friction against the sigmoid notch of the radius.

Radiographic diagnosis of DRUJ arthrosis is usually not conclusive, except in very advanced cases. At surgery we see severe joint cartilage destruction, mainly on the head of the ulna, but on standard radiographs we will not see joint narrowing, osteophytes and subchondral bone cysts, as seen in other weight bearing joints (Fig. 4.16a, b). MRI examinations will be helpful in showing synovitis, which will be best seen on fluid-sensitive sequences, such as a T2-weighted fast spin echo with chemical fat suppression or short time inversion recovery [79]. The most helpful diagnostic test is scintigraphy. A bone scan has high sensitivity and specificity for active bone turnover, but is nonspecific to identify the underlying cause. Differential diagnosis should be made on a clinical basis. An intra-articular infiltration with a local anesthetic will cause immediate temporary relief of pain, confirming the diagnosis.

Clinical Pearls

- Primary degenerative arthritis of the DRUJ is unusual
- Painful DRUJ is usually secondary to fractures or ligament injuries
- Pathology of the DRUJ is seldom diagnosed only on radiographic examination.

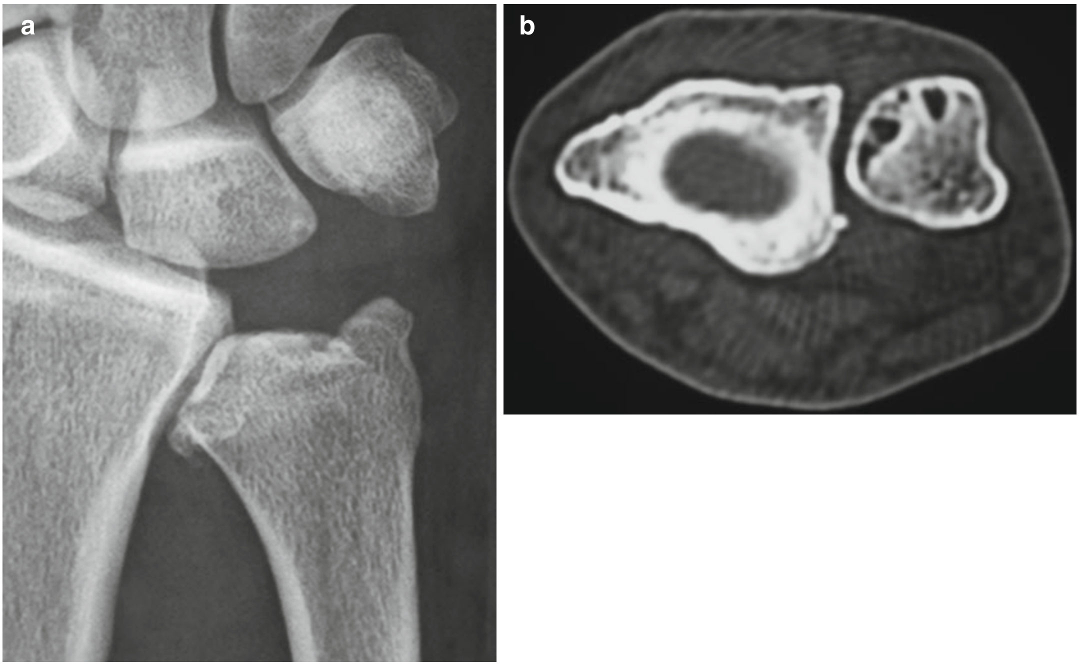


Figure. 4.16 (**a**) Antero-posterior radiograph of the DRUJ showing joint irregularity and small proximal osteophytes. (**b**) CAT scan demonstrating subchondral cysts on the head of the ulna

Treatment

Many procedures have been described for the management of the altered distal radio-ulnar joint (DRUJ). As the arthrosis is due to a broad spectrum of pathology there is no single procedure superior to another, and different surgical techniques must be considered for each lesion.

Resection of the Head of the Ulna

Resection of the ulna head was first described by Joseph François Malgaine in 1855 [80], by Moore in 1880 [81], and popularized by William Darrach in 1913 [82]. It is an easy procedure to perform with early good functional results. Darrach reported one case in which the patient regained full forearm rotation 5 weeks after surgery. Resection of the distal end of the ulna was very popular many years ago for the treatment of secuelae of fractures of the distal end of the radius, which often healed with shortening and angulation. As a consequence, the ulna was longer, causing ulno-carpal impingement and restriction of forearm rotation.

It was not until 1982 that Ekenstan et al. [83] first reported complications related to the resection of the head of the ulna. Other publications commented that this procedure was not free of complications, particularly if an excessive amount of ulna was excised [84]. These problems consisted mainly of instability of the proximal ulna and loss of grip strength. Bell et al. [85] introduced the term “ulnar impingement syndrome” to describe painful clicking of the ulna against the radius on forearm rotation. Radiographs showed scalloping of the distal radius at the site of impingement of the distal ulna stump.

Tulipan et al. [86] performed a resection of the head of the ulna at the level of the proximal end of the sigmoid notch of the radius and sloping proximally on the opposite side to prevent a bony prominence under the skin. Through a dorsal 3 cm incision, Di Benedetto et al. [87] performed an excision of the ulna head leaving it just 3–4 mm shorter than the radius. Both reported better results after minimal excision of the head of the ulna, therefore defending the Darrach procedure after modification of the original technique. What they really accomplished was not to disturb the interosseous membrane and the pronator quadratus muscle, the latter being the main stabilizer of the distal ulna stump.

It has subsequently been recognized that the head of the ulna is an important load bearing mechanism for wrist function [88, 89].

Partial Resection of the Head of the Ulna

To avoid the above mentioned possible complications, techniques of partial resection of the ulna head, while preserving the ulna styloid and the ligaments inserting at its base, have been described. Bowers [90] proposed a resection of the cartilage of the head of the ulna with interposition of a tendon slip to prevent the tendency of approximation of the distal ulna to the radius causing pain from bone impingement. This technique is not indicated in cases where arthrosis is secondary to instability of the distal ulna, or when the ulna is longer than the radius. In these cases, the styloid process of the ulna will cause impaction with the triquetrum, particularly during ulnar inclination of the wrist.

Watson et al. [91] proposed a slightly longer excision of the end of the ulna to match the shape of the distal radius, with the aim of preventing recurrence of pain from joint impingement. The distal ulna was reshaped for about 5–6 cm in length, obviating for soft tissue interposition. However, close to 10 % of the patients had painful radio-ulnar impingement, requiring a second operation [92].

Silicone Implant Arthroplasty

Swanson [93] proposed to excise the head of the ulna and cover the bone stump with a silicone cap: *Silastic ® (Dow Corning. Midland, MI. USA*). The implant had a stem which was fitted into the medullary canal of the ulna. This procedure has been abandoned for the treatment of degenerative arthritis due to an unacceptable rate of complications, such as bone resorbtion underneath the cap, causing tilting of the implant, and also ruptures of the stem.

Hemiarthroplasties

To overcome the complications related to the excision of the head of the ulna, the use of a variety of types of partial or total joint implants has been proposed.

In 1998, Scoonhoven, Herbert and Krimmer [94] designed a rigid implant to substitute the head of the ulna. This was called the *UHP Herbert ulnar head prosthesis* ® (*KLS Martin Group. Tuttlingen. Germany)* and had two components: a conical titanium stem for press fit and later bone in-growth, with three collar designs, and a ceramic head of three different sizes. Although some type of capsular reconstruction can be done at the time of the surgical procedure, the use of this implant is not recommended in cases of major instabilities of the DRUJ.

A similar modular ulnar head replacement was designed at the Mayo Clinic [95]. This was called the *uHead* ® *(Avanta Orthoopaedics Inc. San Diego, CA. USA),* and later manufactured by *Small Bone Innovations. Morrisville, PA. USA*. It has an intramedullary stem made of chrome-cobalt, with a titanium sprayed finish, and has two stem-neck designs. The head of the implant is semispheric and made of cobalt-chrome alloy. The ulnar head component has two holes that can be used for fixation of soft tissues to provide stabilization.

Masaoka et al. [96] performed a biomechanical analysis of the two previously described implants, in fresh frozen cadaver wrists, and both maintained near-normal biomechanics of the DRUJ as compared to a resection of the head of the ulna. However, on radiological examination in living patients, bone resorbtion of the distal ulna, related to stress shielding, was observed in the majority of cases in the two previously described implants. Another radiological observation was a radial sigmoid notch erosion opposite the implant.

A radial sigmoid notch hemiarthroplasty has been designed to add stability to the *uHead* ™ implant at the time of surgery or as a secondary procedure: *Stability*™ *Sigmoid Notch* (*Small Bone Innovations. Morrisville, PA. USA*). This is a modular implant with two components: a cobalt chromium radial plate, plasma sprayed with CPTi, and a UHMW polyethylene insert fixed to the plate. The radial plate is fixed to the distal radius by means of a distal peg and a proximal cobalt chrome screw. This can also be used in cases with painful wear of the sigmoid notch of the radius as seen after some ulna head implants.

Kopylov and Tagil [97] designed a one piece metallic ulna head implant in which the ulna head has the shape of an asymmetrical hemi-cylinder, called *First choice DRUJ system ® (Ascension Orthopedics, Inc. Austin, TX. USA)*. Its design allowed for some preservation of the ligament insertions into the styloid process of the ulna.

Garcia-Elias [98] designed an ulna head implant called *Eclypse ® (Bioprofile. Grenoble, France*), to substitute the damaged portion of the ulna head, for the treatment of DRUJ arthrosis. It has two components: a titanium stem implanted inside the medullary canal of the ulna and a hemispheric ulna head made of pyrocarbon. The ulnar stem has a distal peg into which the head is stabilized. It provides a loose fitting of the ulna head component which allows for some proximo-distal translation and slight axial rotation to adjust its position in relation to the sigmoid notch concavity of the radius on pronation and supination of the forearm. The advantage of this design is that it can be inserted without detaching the foveal insertion of the triangular fibro-cartilage and preserves the extensor carpi ulnaris sheath intact. The preliminary results are very encouraging, as it has the best design for the treatment of DRUJ degenerative arthritis without causing instability of the ulna head.

Total DRUJ Implant Arthroplasty

Scheker [99, 100] designed a total implant arthroplasty with a semiconstrained ball and socket design: *APTIS ® (APTIS Medical. Louisville, KY. USA)*. The ulnar stem was originally manufactured with 316 L stainless-steel and later changed to cobalt chromium to increase strength. The stem has a highly polished distal peg into which the ball is fitted, allowing proximal-distal migration of the ball during pronation and supination of the forearm. This ball is made of UHMW polyethylene and comes in three sizes. The radial component is a plate which is fixed to the radius with a peg at the level of the sigmoid notch and five proximal cortical screws. At the distal end of the plate there is a socket to accommodate the sphere.

Laurentin-Pérez et al. [101] reviewed the results of 31 implanted prosthesis at an average follow-up of 5.9 years (from 4 to 9 years), only reporting two fractures of the stem inside the ulna as the main complication.

The preliminary results of many of the available prostheses are encouraging, although some of them have an unacceptable complication rate, and their cost-benefit has not yet been established.

Arthrodesis of the DRUJ with Proximal Pseudoarthrosis of the Ulna (The Sauvé-Kapandji Procedure)

In 1921, Baldwin [102] reported restoration of pronation and supination of the forearm, after malunited distal radial fractures. A pseudoarthrosis of the ulna was created after excision of a 2 cm segment of bone proximal to the DRUJ.

In 1936, Louis Sauvé de Gonzagues and Mehmed Ibrahim Kapandji [103] described a similar technique, with the variant that a DRUJ arthrodesis was added to the pseudoarthrosis of the ulna. This technique was attributed to Lauenstein by Arthur Steindler [104] in his book on "The traumatic deformities and disabilities of the upper extremity", and for many years he was referred as the author of this technique in the English medical literature [105]. What Carl Lauenstein, from Hamburg, had actually described was a resection of the head of the ulna [106]. However, the so called Sauvé-Kapandji technique had already been published by Berry [107, 108], from New Zealand, in 1931. This procedure had been done the year before, the only difference being that instead of screws or Kirschner wires a bone peg was used to stabilize the DRUJ arthrodesis.

Arthrodesis is the most reliable and durable surgical procedure for the treatment of a joint disorder, despite the main disadvantage of loss of motion of the fused joint. However, the distal radio-ulnar joint can be arthrodesed, while forearm pronation and supination are maintained or even improved by creating a pseudoarthrosis of the ulna just proximal to the arthrodesis. This is known as the Sauvé-Kapandji (S-K) procedure.

The S-K differs from the Darrach procedure in that it preserves ulnar support of the wrist, as the distal radio-ulnar ligaments and ulno-carpal ligaments are maintained. Aesthetic appearance is also superior after the S-K procedure, as the normal prominence of the ulna head, most noticeable when the forearm is in pronation, is not lost. It also allows for unlimited shortening of the ulna head, which cannot always be done with resection arthroplasties that preserve the length of the styloid process of the ulna.

Just as in any surgical procedure there can be complications, but by using this technique only three are directly related to the procedure: nonunion or delayed union of the arthrodesis, fibrous or osseous union at the pseudoarthrosis and painful instability of the proximal ulna stump. The first two are not of much concern as they can be easily addressed. However, a painful instability of the proximal ulna stump can cause a serious disability, which in most cases can be very difficult to correct. Such complications can be prevented if one follows a careful surgical technique [109–112]. Another advantage of the S-K technique is that the postoperative immobilization period is shorter, which is an added benefit for the patient.

Nonunion of the arthrodesis will not occur if a malleolar or other compression lag screw is used for internal fixation [113], as it provides excellent stability as well as compression of the bone surfaces (Fig. 4.17a–c). Some authors recommend using a segment of the ulna that has been resected as a bone graft [114–116]. We do not recommend interposing a bone graft between the radius and ulna, as this creates an unnecessary barrier of devascularized tissue, particularly if cortical bone is used. There are no strains or transmission forces through the head of the ulna and therefore it is rare to observe a pseudoarthrosis [117]. Following Kapandji's recommendation [118, 119], most surgeons favour the use of 2 screws, or 1 screw and a Kirschner wire, for the internal fixation. It is true that the head of the ulna can rotate around the axis of the screw during insertion, which should be controlled by the surgeon, but this will never occur after the joint surfaces are engaged under compression. Removing large amounts of ulna, as well as interposing a flap of the pronator quadratus (PQ) muscle, with the aim of decreasing the probability of fibrous union at the pseudoarthrosis will have the deleterious effect of increasing instability of the stump of the ulna [120–128].

The pseudoarthrosis should be created just proximal to the ulnar head, leaving a bone defect no larger than 5 mm. There are three reasons for making the most distal pseudoarthrosis possible. One is to create the pseudoarthrosis as close as possible to the axis of rotation of the forearm, which runs obliquely from the centre of the radial head proximally to the centre of the ulna head distally. An osteotomy done at a more proximal level will cause a divergence of movements between the osteotomized ends of the ulna. Another reason is that the proximal stump of the ulna will contact with the radius in a relatively flat triangular shaped surface, proximal to the sigmoid articular facet of the radius, measuring on average 20.5 ± 1.3 mm in length, which serves for insertion of the deep head of the PQ muscle [129] (Fig. 4.18). Finally, is not to disturb the static and dynamic structures which provide stability to the proximal ulna: the pronatus quadratus muscle [130–133] (Fig. 4.19), the ECU muscle and tendon [134, 135], the FCU muscle and the interosseous membrane insertions [136–138].

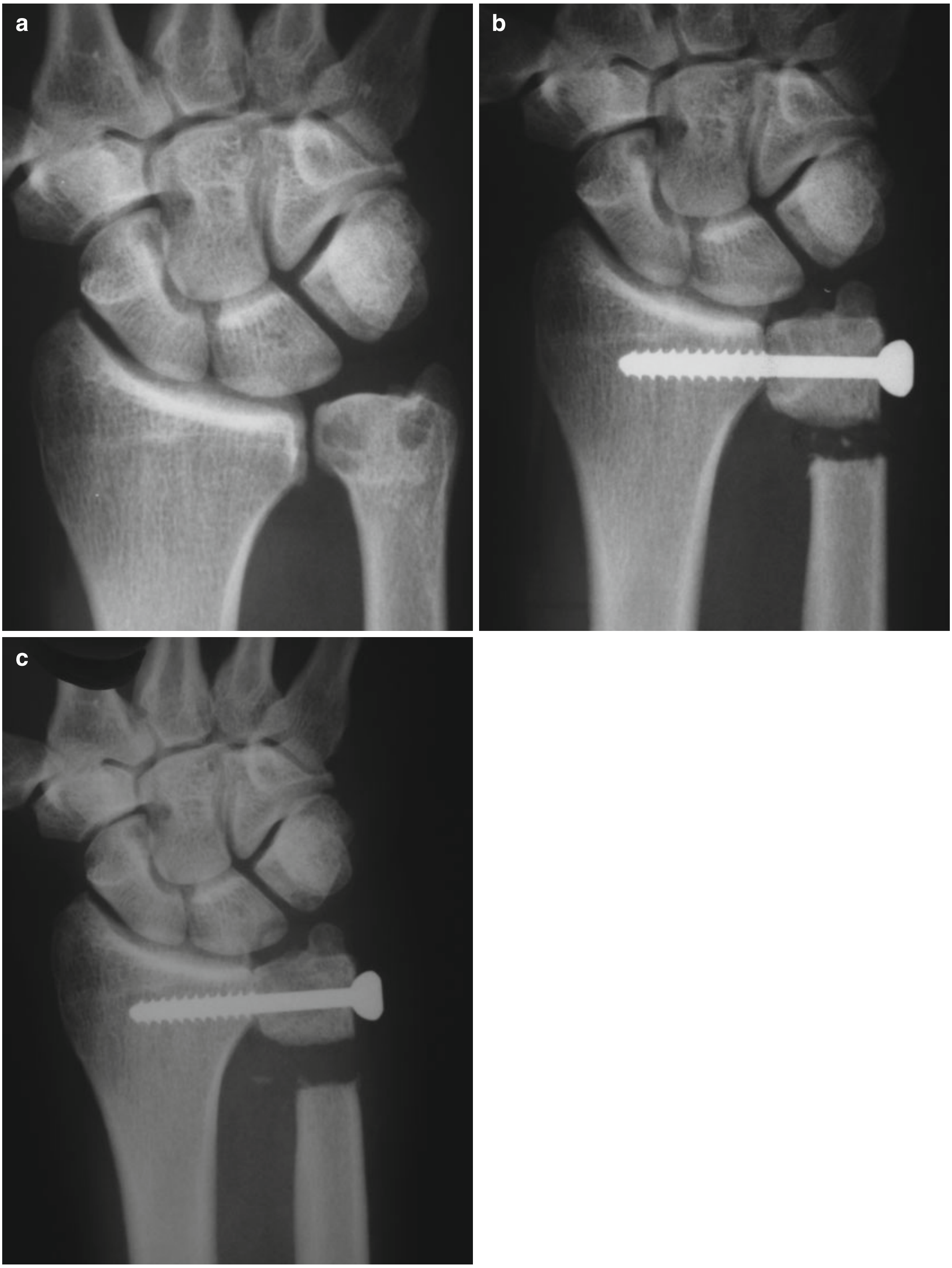


Figure. 4.17 (**a**) Degenerative arthritis of the DRUJ. (**b**) Early postoperative radiograph of a Sauvé-Kapandji procedure creating a very distal pseudoarthrosis of the ulna with minimal bone resection. (**c**) A few weeks after the procedure, the ends of the osteotomized ulna show some shortening and remodeling

Figure. 4.18 Photograph showing the sigmoid notch of the radius and the flat trapezoidal shaped area, proximal to it, where the proximal stump of the ulna should contact

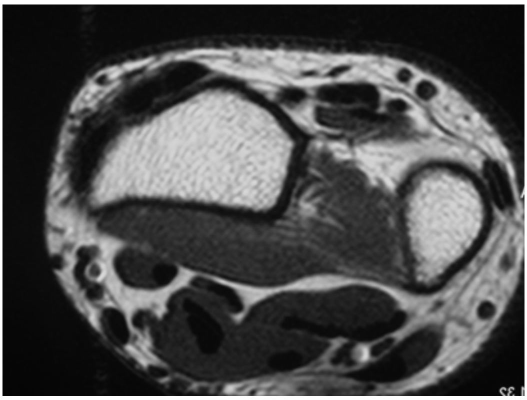


Figure. 4.19 MRI of the DRUJ showing the two heads of the pronator quadrates muscle. The deep head is the main stabilizer of the head of the ulna and should not be disturbed when performing surgery to the distal end of the ulna

Clinical Pearls

Many surgical procedures have been proposed for the treatment of DRUJ arthrosis

The choice of surgical treatment should be based on the primary cause of the arthrosis

Resection of the head of the ulna is the easiest and most effective procedure for pain relief, but it may cause instability of the proximal ulna stump

The Sauvé-Kapandji procedure can be used for the treatment of all causes of a painful DRUJ. The main complication of this procedure, if not properly done, is instability of the proximal ulna stump, which is again quite difficult to treat.

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