Fractures of the Distal Radius: a Contemporary Approach

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Abstract. The fracture of the distal radius is the most common fracture we treat. Although sometimes stated otherwise, the outcome of these fractures is not uniformly good regardless the treatment instituted. A thorough understanding of the anatomy and biomechanics of the wrist is a prerequisite when treating these lesions. The literature proves that there is a strict relationship between the quality of anatomical reconstruction and the long-term functional outcome. We try to clarify the complex functional anatomy of this region.

Epidemiology and fracture mechanism

The fracture of the distal radius accounts for 10-25% of all fractures seen at our emergency department (2).
Traditionally a bi-modal incidence peak is described. A first peak is seen in young men related to high-energy trauma; a second much more important peak is recorded in the post-menopausal female and is related to low-energy trauma. A clear relationship to osteoporosis (3) and repeated falling (4) can be demonstrated. It is typically the middle-aged female patient who, being less debilitated than the more elderly - tries to stop her fall and lands on the outstretched hand. The more debilitated elderly person lacks this defensive response and lands directly on her/ his hip. This can explain why hip fractures become more frequent than wrist fractures in females older than seventy-five. Especially in the middle-aged group, postural instability is much more present in the female population as in the male, explaining the gender difference in prevalence to some account. Most certainly a wrist fracture can be the signal that postural stability and osteoporotic changes should be investigated and if possible corrected. If not, it can be the start of a series of osteoporosis-related fractures to the hip, vertebral column and proximal humerus.

The fracture with dorsal dislocation (Pouteau or Colles’ fracture) has traditionally been seen as the extension fracture, caused by a fall on the outstretched hand and the fracture with volar displacement (Smith-Goyrand) as the flexion fracture caused by a fall on the hyperflexed wrist. This view has been challenged by both STOFFELEN (5) and PECHLANER (6), both proving that every fracture pattern can be caused by a fall on the outstretched hand with exclusion of the avulsion fracture. In the female osteoporotic bone in 90% of all cadaver models resulted in a fracture loco typico, in the male only in 55% of the models a fracture loco typico could be realized.

In a prospective one-year study in Bergen (Norway), a fall while walking was the most common cause of fractures of the distal radius. In this study, fractures of the distal radius occurred twice as often as fractures of the proximal humerus in the same population, but persons sustaining fractures of the distal radius were relatively more healthy and active than those sustaining a fracture of the proximal humerus (7).

Classification

There will only be few body regions in which as many eponymous classification systems exist as for the distal radius. Many of them are merely of historical interest. A good classification system should have a low inter- and intra-observer variance, should be easy to use, should be easy to compute, should have a prognostic value and should have direct therapeutic consequences. Many of the proposed systems tend to have these advantages, but mostly the inter- and intra-observer reproducibility seems to be a major problem. The AO/ASIF classification as proposed by MÜLLER (8) seems to combine most of the required criteria, although this is also controversially discussed. The classification differentiates between non-articular (A-type), partially articular (B-type) and complete articular (C-type) fractures. The further differentiation is based on comminution and direction of fracture lines. This results in 27 subgroups which are useful for scientific differentiation. In daily praxis, the 9 groups are more useful (Fig. 1).

Functional anatomy

Of course, the thorough description of the anatomy of the distal radius and carpal region is not the scope of this article. On the other hand, a basic knowledge of the functional anatomy is a prerequisite for fracture understanding and good treatment.

The articular surface of the distal radius is biconcave and triangular with the apex of the triangle directed towards the styloid process, the base represents the sigmoid notch for articulation with the ulnar head. The surface is divided into two facets by a well-defined ridge. One facet, the fossa lunata articulates with the lunate bone; the second, the fossa scaphoidea articulates with the scaphoid bone.

The volar surface of the distal radius is relatively flat. It is covered proximally by the pronator quadratus muscle. The flexor tendons and the median nerve lay more superficially. The dorsal surface is convex. Between the second and the third extensor compartment there is a bony ridge, Lister’s tubercle. The extensor tendons are only separated from the bony surface by the floor of the extensor retinaculum and the periostium. These anatomic relations between the six extensor compartments, the retinaculum extensorum and the dorsal radial cortex are of extreme importance for the dorsal surgical approaches to the distal radius. The direct articulation between the distal ulna and the carpus is less important. It is covered by a complex cartilaginous structure, the triangular fibro cartilaginous complex (TFCC). It is the development of this TFCC combined with the lack of a true ulno-carpal joint that differentiates the hand of the human of that of lower primates and gives the human wrist its extreme freedom of movement. On the other hand, the TFCC is a structure that is very sensible to trauma and degeneration and can be a source of ulnar wrist pain that is difficult to treat.

The distal radio-ulnar joint (DRUJ) is of equal importance as the radio-carpal joint. It is composed of the fixed ulnar head and the sigmoid notch. This sigmoid notch not only rotates around the ulnar head, but it makes at the same time a translational movement. In pronation, the ulnar head moves dorsally in the sigmoid notch; in supination it is displaced anteriorly. The most important stabilizer of the DRUJ is the TFCC,
additional stabilizers are the interosseous membrane of the forearm, pronator quadratus muscle and the tendons and sheets of the extensor and flexor carpi ulnaris muscles. As the interaction of all of these structures is of the utmost importance for stability and motion, deformity after injury or fracture has an important influence on the function of the entire wrist.

The bony architecture of the distal radius can be viewed in terms of columns. RIKLI and REGAZZONI (7) divided the distal forearm in three columns: the medial column consisting of the ulna, the TFCC and the DRUJ; the intermediate column made up of the fossa lunata and the sigmoid notch and the lateral column including the fossa scaphoida and the styloid process. Fracture lines often run between these columns. The intermediate column can also be split in a sagittal plane, creating the dorsal and the volar intermediate fragment. The surgical reconstruction of the distal radius should be based on the knowledge of these columns. Almost 80% of the transmitted forces go over the distal radius by longitudinal loading of the wrist, if radius and ulna are equally long (ulna neutral). Lengthening of the ulna shifts force transmitting in the direction of the ulna, whereas ulnar shortening shifts forces towards the radius.

**Radiological anatomy**

Besides the knowledge of the bony and ligamentous architecture of the distal radius, the surgeon treating fractures of the distal radius needs to have a thorough knowledge of the radiological anatomy of the wrist. One considers the ulnar inclination, the palmar inclination, the radial length, the ulnar variance and the radial width. Ulnar inclination (Fig. 2) is defined as the angle between a line perpendicular to the long axis of the radius and a line drawn from the tip of the radial styloid process to the ulnar corner of the articular surface of the distal radius. The mean ulnar inclination is 22-23°. There is however a strong interindividual variability and strong
influence of choice of anatomical landmarks and positioning (pro-supination).

Palmar inclination (Fig. 3) is defined as the angle between a line connecting the most distal point of the dorsal and palmar cortical rims and a line perpendicular to the longitudinal axis of the radius. The angle is on average 10-12°, but again an interindividual variability of 4-22° among normal individuals is observed.

Radial height (Fig. 4) is measured on an AP-radiograph. It is the distance between two lines perpendicular to the long axis of the distal radius; the first one going through the tip of the styloid process, the second one at the level of the articular surface of the ulnar head.

The distance between a line parallel to the fossa lunata and a line parallel to the ulnar head is considered to be the ulnar variance (Fig. 5). This should be compared with the uninjured side as again interindividual variance is large (ulna – 2mm to + 2 mm). In case of a fracture, the ulna is mostly in a relatively positive variation due to the shortening of the radius.

Radial width (Fig. 6) is defined as the distance between two lines parallel to the longitudinal axis, one going through the most lateral tip of the styloid process and one going through the centre of the radius on an AP-radiograph. An increased radial width as compared with the non-injured side is a strong indication for rotational malalignment and as such a predictor of bad functional outcome.

Additional radiological investigations can be of value. The true comminution at the articular surface and the dislocation of intra-articular fragments can better be
judged on computed tomography. Of course, this should not be part of the routine investigations for distal radius fractures. Arthrography or computed tomography with intra-articular contrast can be of value to detect associated lesions of the intrinsic carpal ligaments and/or the TFCC. Theoretically, MRI seems to have the same potential, but its feasibility and accuracy in the acute setting still has to be proven by well documented series, as some of the published early experiences show a rather low sensitivity and specificity (8). After stable fixation, cinematography can be used intra-operatively to demonstrate ligamentous instabilities at the wrist (9).

Treatment goals

As for all fractures, the goal of the treatment should be to restore function of the affected wrist at the best, to limit pain as much as possible and to reach this goal as soon as possible. Socio-economic goals should be taken into consideration too (a discussion falling out of the scope of this article) at the lowest possible price. When considering these goals, it must be clear that no single therapy can be offered for all fracture types and that patient specific criteria (biological age, degree of osteoporosis, pre-existing limitations, etc.) are often more indicating what therapy should be offered than pure anatomical considerations.

In case of intra-articular fractures (i.e. when the radio-carpal joint is involved), the work of Jupiter demonstrates that anatomical reconstruction is of utmost importance to obtain good functional results (10). According to this study, an intra-articular step of more than 2 mm inevitably leads to osteoarthritis and a functional deficit. Many authors agreed to this statement, some even stated that an intra-articular step of 1 mm is unacceptable. Beside the anatomical reconstruction,
timely diagnosis and treatment of associated intra-articular lesions seems to be of importance too. Some series report associated TFCC-lesions in up to 60%, SL-lesions in up to 85% an LT-lesions in 61% of cases (11). Although conventional radiography, intra-operative cinemagraphy and intra-operative arthrography can help us to diagnose associated lesions, arthroscopy seems to be the most sensitive and specific and offers the possibility to treat the diagnosed lesion immediately. Especially fracture lines going into the direction of the SL-band seem to be correlated to a very high percentage of SL-band lesions.

Not only the radio-carpal joint is of importance to the outcome. As already stated by Frykmann in 1967 (12) and later confirmed by Melone (13) and Fernandez (14) among others, incongruence at the distal radio-ulnar joint leads to a painful and function-limiting arthritis. This painful condition can be hard to treat, making salvage procedures such as the Sauvé-Kapandji or Darrach procedure necessary. These can often bring pain relief, but limit power and range of motion.

Malalignment at the metaphyseal area leads to a changed load distribution at the wrist joint as demonstrated by Taleisnik and Watson (15). Fernandez demonstrated that this leads to a loss of motion and the development of osteo-arthritis at the wrist joint (14). Here corrective measures, even in the older non debilitated patient, can bring a gain of function and a reduction of pain (16). Radial shortening, often seen after fractures of the distal radius, leads to a radio-ulnar incongruence (17), subluxation of the ulnar head at the DURJ and painful impingement of the TFCC (14). The amount of metaphyseal comminution is related to the shortening and the tendency to loose radial length, even after adequate reduction. As such Batra (18) calls the radial shortening the most important factor to determine the outcome after fractures of the distal radius.

One could summarize the above-criteria stating that anatomical reduction of both the metaphyseal area and the radio-carpal and distal radio-ulnar joint are essential to obtain good functional results. This is stressed by many studies proving the good correlation between radiological and functional outcome in fractures of the distal radius.

### Conservative treatment

Of course, the conservative treatment of fractures of the distal radius still has its place in our treatment protocol. It is the treatment of choice for all undisplaced fractures and all “stable” fractures of the distal radius showing less than 10° of dorsal angulation, less than 1mm of lateral shift and less than 2 mm of initial shortening. Articular fractures should have an articular step of less than 2 mm (1 mm in young patients). When we obtain a stable, anatomical closed reduction we can treat the fracture non-operatively.

Discussion exists about how to immobilise the wrist in case of conservative treatment of fractures of the distal radius. “There”, and I cite the Cochrane Database, “remains insufficient evidence from randomised trials to determine which methods of conservative treatment are the most appropriate for the more common types of distal radius fractures in adults. Therefore practitioners applying conservative management should use an accepted technique with which they are familiar, and which is cost-effective from the perspective of their provider unit. Patient preferences and circumstances, and the risk of complications should also be considered” (19).

Initially non-displaced fractures can be treated by immediate mobilisation. One can immobilise for one week for comfort reasons. Immediate mobilisation does
not result in secondary displacement, but results in an earlier functional recovery (5).

Earlier severe palmar flexion and ulnar deviation has been advocated to prevent secondary dislocation after reduction. This should however never be necessary. This position not only puts more pressure on the carpal tunnel structures, but it is a non-physiological immobilisation position leading to soft tissue- and vascular complications (22).

Whenever choosing to treat a fracture non-operative-ly, we have to ensure that no secondary dislocation occurs. This means that radiological re-evaluations are necessary on a regular base until sound fracture healing becomes obvious. (Fig. 7). Whenever secondary displacement occurs, surgical reconstruction in an early stage yields better results than later reconstruction (20). A second attempt of closed reduction and cast immobilisation only gives a good or excellent result in one third of all cases (21).

In the older debilitated patient, a good functional outcome should be judged to other criteria than in the young patient. Malalignment is often tolerated relatively well in these patients already having a limited functionality and the development of arthritis seldom becomes painful before the end of their lives. Closed reduction is of no use in these patients as redislocation almost always

Fig. 7
Failed conservative treatment (closed reduction) in a 25-year old female
occurs despite reduction and immobilisation as clearly demonstrated by Beurmer et al. (23). In these patients, the fracture should be immobilised until sound fracture healing is documented. No further treatment should be initiated.

**Percutaneous pinning**

The Cochrane database (30) states that there is no evidence for choosing a particular operative treatment for unstable fractures of the distal radius. It is difficult to discuss percutaneous pinning as there are almost as much pinning techniques, as there are surgeons treating fractures of the distal radius. The advantages of percutaneous pinning are: K-pins are readily available in most hospitals of the world, it is a low cost technique, it augments the stability of the reduction (or at least it should) and it allows, when used as joy-sticks, exact reconstruction of the joint surface and metaphyseal area.

The disadvantages are: the need for an additional immobilisation (plaster of Paris or external fixation), the risk of pin-tract infection, the risk of injuring neuro-vascular structures or tendons, the risk of hardware migration and the risk of secondary displacement after pin removal.

In young patients, percutaneous pinning can be beneficial. The good bone quality often allows for a relatively stable reduction, of which the stability can be augmented by pinning. There is no evidence that proves one pinning technique to be superior to the other. The use of Kapandji intrafocal pinning is however limited to relatively simple extra-articular fracture patterns (5). The functional benefit in these rather simple fracture patterns also has to be questioned as in a randomised prospective trial conducted at our institution no benefit in functional nor in radiographic outcome at one year for Kapandji pinning as compared to closed reduction could be demonstrated (24).

Although many authors report favourable outcome after closed reduction and percutaneous pinning, some series show disastrous results. Sommer among others reports a 93.3% secondary fracture dislocation rate after percutaneous K-wire pinning (25). The reason for this high percentage of secondary displacements, often related to an angulation resembling the initial displacement, is the comminution of the dorsal metaphyseal cortex.

After reduction an enormous hole is left in this metaphyseal area. This hole can make the reposition, even in the presence of wire fixation, so instable that reduction is lost. When the hardware is removed after 6 weeks, this hole is not yet filled with bone. This allows - in combination with the still elastic callus - for secondary displacement at the volar side. Many groups tried to solve this problem by augmenting their reduction and pin fixation with a bone substitute. In the younger patient autologous bone grafts are used, in the older patient one can use homologous grafts or one of the various commercially available bone substitutes or bone cements. This augments stability and prevents theoretically secondary displacement. Biomechanical analysis shows that the use of calcium phosphate bone cement alone is insufficient to withstand physiologic flexion-extension motion of the wrist without supplemental wire fixation. When supplemented with K-wires, fixation with bone cement is more stable than are K-wires alone, but is significantly less stable than a cement augmented external fixation (26). Of course this augmentation, especially when autologous bone grafts are used, makes the treatment much more invasive. These augmentive techniques are also of use in stabilizing articular fragments, by supporting them through filling up the metaphyseal cavity.

**External fixation**

The use of joint bridging external fixation to treat fractures of the distal radius is widely accepted. It is based on the principle of ligamentotaxis. By distracting the joint area, the fragments are reduced by traction on the capsuloligamentous attachements. Sometimes an additional reduction is achieved by creating a vacuum in the joint. The latter may explain how successful reduction of fragments without capsular attachment can be achieved in some cases. By maintaining the traction throughout the healing process, the fragments are kept aligned. The negative effects of the maintained traction can be the creation of extrinsic extensor tightness and a loss of radiocarpal and intercarpal motion. Furthermore extensive traction can be associated with an increased risk of algoneurodystrophy. When excessive traction is needed to maintain reduction, additional fixation by K-wires should be used in order to allow for lower distraction forces. Filling up the metaphyseal defect by autologous bone grafts or bone substitutes can also add extra stability (Fig. 8).

Furthermore the external fixator can be used as a device to neutralize forces acting on an unstable osteosynthesis or in anatomically reduced extra-articular bending fractures. In case of high-energy fractures with meta-diaphyseal comminution and/or bone loss, the fixator can be used to bridge the defect and to act as a buttress.

Some authors advocate the use of non-joint bridging fixators to overcome the problem of radio-carpal and intercarpal loss of motion. The use of these fixators is limited to extra-articular fractures in which the distal fragment is large enough to accommodate two pins, which can be placed transversally. In case of simple articular fractures, one can first reconstruct the joint block using pins or screws and fix this reconstructed block to the diaphyseal fragment using an external
fixator. In this kind of construction, the fixator is often used in a compression mode. In multifragmentary articular fractures or fractures with a very small distal fragment, this approach is not applicable. For those cases some authors developed a “dynamic external fixator”. This device allows movement in the radiocarpal joint. The potential advantages: less stiffness, earlier return of function, better reconstruction of the articular cartilage and reduction of digital stiffness could however not be confirmed by Sommerkamp (27) in a prospective randomized study.

Whenever using techniques with transcutaneous materials, such as K-wires or Schanz screws, meticulous pin-care is essential to avoid pin-tract infections. Traction of the pins on the skin is associated with a high incidence of pin tract-infections and thus should be avoided by properly placed and large enough skin incisions.

It can be useful in comminuted fractures to use the external fixator as temporary reduction and fixation tool to allow for more precise evaluation of the fracture and the associated soft tissue lesions. Then a more accurate definitive treatment can be installed.

Arthroscopy

Arthroscopy as such does not reduce the fracture or stabilize it. It can however be of value in articular fractures, especially in the younger patient. Arthroscopy offers the opportunity to control the quality of the articular reduction. Under direct vision, fragments can be manipulated percutaneously or with K-wires as joy-sticks. When perfect articular reduction is obtained, the K-wires introduced for fragment manipulation can be advanced in adjacent fragments to secure reduction. If necessary, reduction clamps can be used percutaneously to obtain interfragmentary compression.

To ascertain the reduction of the articular bloc to the shaft, supplementary techniques such as pinning, external fixation or plate osteosynthesis have to be used, depending on the fracture type, the surgeons experience and the patient’s preferences.

Besides controlling the articular reduction, arthroscopy allows us to diagnose associated carpal lesions. Articular fractures of the distal radius are associated with high incidences of SL-band lesion, LT-band lesions and TFCC ruptures. SL-band lesions are reported with a frequency varying from 20% to 85% (11, 28). Sagittal fractures of the distal radius and fractures with avulsion of the styloid process of the distal radius seem to be associated with a very high incidence of SL band lesions. Early repair of these lesions, often by simple reduction and pinning, is related to a better outcome. LT-band lesions are much less frequent, but here again; early treatment results in a better outcome. TFCC lesions are reported in 50-60% of articular distal radius fractures. There still is much controversy about the radial avulsion lesions and their treatment. Ulnar avulsions,
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that are treated early however seem to have favourable results (29).

**Screw osteosynthesis**

In avulsion fractures or sagittal split fractures of the radial styloid process, a stable osteosynthesis can often be achieved by using one or two lag screws through the styloid.

In most cases, the stability of this osteosynthesis is big enough to allow for immediate mobilisation. If the fragment is too small, percutaneous pinning can be necessary combined with plaster cast immobilisation.

**Plate osteosynthesis**

Almost all authors have considered plate osteosynthesis by as the best solution for volar displaced (Smith) fractures of the distal radius (31). The buttressing effect of the plate, if necessary augmented with screws in the distal fragments, yields in most cases of A- and B-type fractures in good or excellent results. Of course, the amount of intra-articular comminution and the consequent quality of articular reduction are predictive for the outcome in C-type fractures.

Volar plating for dorsally displaced fractures has the problem that the plate was laying at the opposite site than the direction of dislocation. The plate can thus not act as a buttress and the poor quality of bone in this area does not give much grip for the screws to act as pulling screws. Often loss of reduction can be witnessed.

Dorsal plating, certainly with 3.5 mm plates was often complicated with extensor tendon problems. The extensor tendons run directly over the implant and adhesion between the plate and the tendons or even secondary tendon ruptures are often seen (32).

Rikli and Regazoni (7) tried to solve this problem using smaller implants (2 or 2.4 mm), placed in a dorsal and lateral fashion based on their three pillar concept. The smaller size and smooth titan polishing reduce the risk of tendon irritation, but cannot eliminate it completely. The smaller size and two plate technique make it also possible to have more screws in the distal fragment, allowing for reconstruction of complex fractures.

The angular stable plates make it possible to treat most fractures from the volar side. The screws, which are locked in the plate, are placed just proximal to the subchondral bone. (Fig. 9) Here we can almost always find dense bone. The screws will act as a buttress for this dense bone and theoretically no secondary loss of reduction is witnessed. The relatively large distance between the flexor tendons and the plate and the protection of the pronator quadratus muscle, make flexor tendon problems extremely seldom (33).

We demonstrated the stability of this construction in an unpublished series of 20 unstable fractures of the distal radius in osteoporotic females over 65 years of age, in which a volar angular stable 3.5 mm plate osteosynthesis (LCP Mathys medical) has been performed without bone grafting. In this series, we witnessed no significant loss of reduction or loss of radial length (34). The use of this technique is however limited to A, B and C1-type of fractures. The more complex articular C2-and C3-fractures are not treatable using the 3.5 mm plate alone, since too little screws can be introduced in the distal fragment. A possible solution is to reconstruct the articular block using pins or separate screws and fix this to the meta-diaphyseal fragment using a 3.5 mm plate. Recently, a 2.4 mm pre-shaped plate has been introduced which gives the opportunity to introduce 5 screws in the distal fragment. The pre-shaping of the plate also makes it possible to fixate small distal fragments.

A dorsal approach using 2.4 mm angular stable dorsally and laterally can be used for comminuted fractures, which cannot be reconstructed using a volar plate. This combines the advantages of the Rikli-technique with these of pre-shaped, angular stable plating. In these fractures, the use of a bone substitute into the metaphyseal hole is almost always mandatory. This bone substitute not only serves to prevent secondary dorsal dislocation, but also helps to reduce the articular fragments and to hold them in their reduced position.

In some C2-C3 fractures, we combine a dorsal and volar approach (Fig. 10) to obtain acceptable reconstruction of the distal radius. Angular stable osteosynthesis in whatever form is normally stable enough to allow for immediate mobilisation, preventing excessive scarring and joint stiffness.
Conclusion

It will be clear there is no tailor-made solution for all fractures of the distal radius. It is important to reconstruct the anatomy of the distal radius as good as possible, since anatomical reconstruction is a prerogative for good functional outcome, especially in the active patient. Only in the debilitated patient, malalignment and articular incongruence can be accepted. In these patients, reduction of the fracture and operative treatment seems to be of no benefit. For all other patients, anatomical reconstruction of the articular surface and the metaphyseal area must be the goal of treatment.

The non-displaced fracture can be treated functionally with little or no immobilization. Stable fractures or fractures that are stable after anatomical reduction are treated conservatively. All other fractures should be treated operatively. As prolonged immobilisation leads to scarring of the soft tissues, stable osteosynthesis allowing for early movement is the therapy of first choice. Immobilisation in an non-natural position should be avoided as it not only leads to stiffness but is also associated with an high incidence of algoneurodystrophy. Only angular stable plates can give long enough resistance to the displacing forces acting on the early callus to prevent secondary displacement in case of a large (dorsal) metaphyseal defect after reduction. If one chooses to use an other form of stabilisation, the use of bone substitutes to fill the defect most seriously should be considered.

In case of articular fractures, the articular surface should be reconstructed anatomically. To do so, arthroscopy can be of use to guarantee the quality of reduction. Furthermore arthroscopy can help us to diagnose associated carpal lesions in an early phase and to treat them as needed. Especially in the younger patient with articular fractures this should be advocated.

The choice of treatment should be based on the fracture type, the patient’s characteristics, the patient’s demands and last but not least on the treating surgeon’s experience and preference. As long as stable reduction and anatomic reconstruction are guaranteed, many ways can lead to a successful treatment of fractures of the distal radius.

References


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