Review Article

Capsula Eburnea

THE CURRENT STATE OF THE ART OF ANGLE-STABLE VOLAR PLATING IN THE TREATMENT OF DISTAL RADIAL EPIPHYSIS FRACTURES

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SUMMARY

Fractures of the distal radius are the most common type of fractures in the upper extremities, accounting for 17% of all fractures treated in the Emergency Department. Treatment techniques are constantly evolving: while the classic treatment of choice involved a plaster cast and immobilization, today, thanks to studies on the biomechanics of fractures and the ongoing innovation in the field of fixation devices, the preferred treatment methods are increasingly geared towards a faster and more physiological functional recovery. In this article, the authors provide a detailed overview of the treatment methods in use today, such as the latest generation of plates and screws used for the reduction and stabilization of fractures, which allow an early mobilization and respect the complex anatomy of the wrist.

Introduction

Wrist fractures account for about 1/6 of all fractures treated in the emergency department [1]. Several epidemiologic studies on these fractures have reported a bimodal distribution with two peaks: in younger patients, wrist fractures are often articular and comminuted due to high-energy trauma [2]; in elderly patients (in their 60s or 70s), often osteoporotic and mainly female (79,5%), the fractures are usually extra-articular, metaphyseal, and caused by falls [3]. The clinical presentation is characterized by pain, deformity and preternatural mobility. Following a radiographic evaluation, the fractures are classified based on the extent of displacement, comminution and articular involvement, determining the prognosis and optimal therapeutic approach. Treatment goals should include achieving an anatomic reduction and maintaining it throughout the healing period, to ensure a full physiological and functional recovery [4]. With the increasingly elderly population, the demand for a better functionality, quality of life and life expectancy is growing. In fact, the last decade has witnessed a gradual increase in surgical treatment of wrist fractures, regardless of the age of the patient, aiming at early mobilization and complication-free healing. In this article, the authors wish to highlight the main radiologic evaluation parameters, classification systems, and the current state of the art for treating distal radial epiphysis fractures by open reduction and internal fixation.

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Diagnostic Imaging

A radiographic assessment is necessary for the formulation of the treatment strategy: this assessment should include images taken in a neutral position (intermediate pronosupination, relaxed and under stress), in posterior-anterior sagittal projection and in latero-lateral projection; moreover, the radius can only be accurately examined in images obtained by placing the hand in a position of hyperpronation [5]. More complex fractures can be studied by Computer Tomography (the 3D reconstruction can be useful for fractures involving the distal radioulnar joint (DRUJ) [6]. Magnetic Resonance Imaging can be used to assess ligaments and triangular fibrocartilage. The radius and the ulna have inclinations and reciprocal relations that need to be respected during the reduction, to avoid altering the biomechanics of the wrist [7]: these include the ulnar slant of the articular surface of the radius (15 - 25 °), palmar tilt (11°), distal radioulnar index (1 mm) and radial height (9-12 mm) [8]. The need for surgery is determined by the presence or absence of radiographic signs of fracture instability: post-traumatic arthritis has been widely documented to be correlated with the degree of imperfection in the fracture reduction (Tab.1).

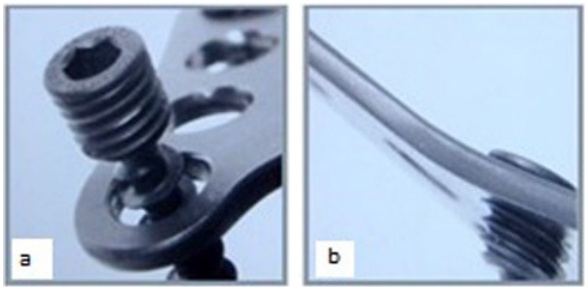

Fig. 1: Angular stability between screw and plate (1a); low profile plate (1.6 mm) (1b). (reproduced, with modifications, from: www.chirurgiadellamanobrescia.it).

Classification

Old eponyms, pre-dating the introduction of radiographic imaging and thus based on deformities observable by physical examination are discouraged, but sometimes still in use. These eponyms, which do not classify fractures according to their prognosis or preferred treatment, include the Colles-Pouteau fracture, the Smith-Goyrand, or reverse Colles fracture, the Barton and reverse Barton fracture, as well as the Hutchinson fracture [9]. The AO classification system, introduced in 1986 by the Swiss *Arbeitsgemeinschaft für Osteosynthesefragen* foundation, is considered the most complete, extensive and detailed [10]. This classification system is organized according to the level of severity, and divided into three main types of fractures; A: extra-articular; B: partial articular; C: complete articular. Each type is further divided into three groups and subgroups, based on the morphologic complexity, difficulty of treatment and prognosis, as well as taking into account eventual distal ulnar lesions [11]. In 1993, Fernandez and Jupiter introduced a practical modification of the AO system, based on the mechanism of injury instead of radiographic characteristics. This classification system includes information on the post-reduction stability and potential ligament injuries associated with the fracture; the Fernandez and Jupiter system is currently being considered as complementary to the AO classification [12].

Treatment

For all fractures, an initial closed reduction and immobilization should be performed, followed by the assessment of the radiographic instability criteria, the age and general condition of the patient, as well as future functional requirements, in order to plan further treatment. Thanks to studies on the biomechanics of fractures and inno-

Tab. 1: Radiographic parameters of instability.

List of radiographic findings indicating the need for surgical treatment:
• *Intra-articular fracture line*
• *Articular step-off or diastasis greater than 2 mm*
• *Displaced fragment(s)*
• *Fracture of the ulnar head or neck may be associated with triangular fibrocartilage lesions or DRUJ Instability*
• *Radial shortening exceeding 5 mm*
• *Marked metaphyseal comminution*
• *Dorsal (or palmar) tilt greater than 20 degrees*
• *Osteoporosis*

vation in the field of fixation devices, novel treatment methods that guarantee a fast and physiological functional recovery are becoming widespread. Recent evolution in plate and screw design include a reduced footprint and a greater stability thanks to the development of adjustable screws and pegs which lock onto the plate (angle-stable fixation: fig. 1a, 1b and 2), applied using less traumatic techniques than in the past, thus helping to conserve the delicate structures of the wrist (volar reduction and fixation) [13]. A retrospective study of more than 2000 cases of distal radius fractures found that 24% of patients were left with a permanent disability. The more serious complications include: restricted motion, chronic pain and loss of grip strength. Lunate collapse has profound effects on the radiocarpal joint. Palmar flexion instability alters axial load distribution, increasing the load on the ulnar side of the wrist and causing reduced grip strength and pain. Radial shortening can cause DRUJ dysfunction (weakness and pain on pronosupination). The symptoms are generally related to the severity of the initial injury. Insufficient reduction is a common risk factor of developing post-traumatic arthritis [14]. An Open Reduction and Internal Fixation (ORIF) can ensure a perfect anatomic reduction, including all fracture fragments, as well as a stable osteo-synthesis and early mobilization for an optimal functional recovery, thanks to the use of angle-stable plates. The plate is initially loosely attached, and adequate reduction and fixation are verified by fluoroscopy. The screws are then tightened to obtain stable internal fixation. To better adapt this fixation device to individual fractures in patients with varying anatomical characteristics, screws and pins with variable angulation have been introduced to support and stabilize articular fragments. This fixation method is recommended for high energy fractures, such as fractures of the dorsal or volar articular margin, as well as for highly unstable, comminuted intra-articular fractures (AO type C3.3) [15]. Bone crafts can be used with this approach to shorten fracture consolidation time and to help avoid secondary displacement by bridging gaps created by compaction [16].

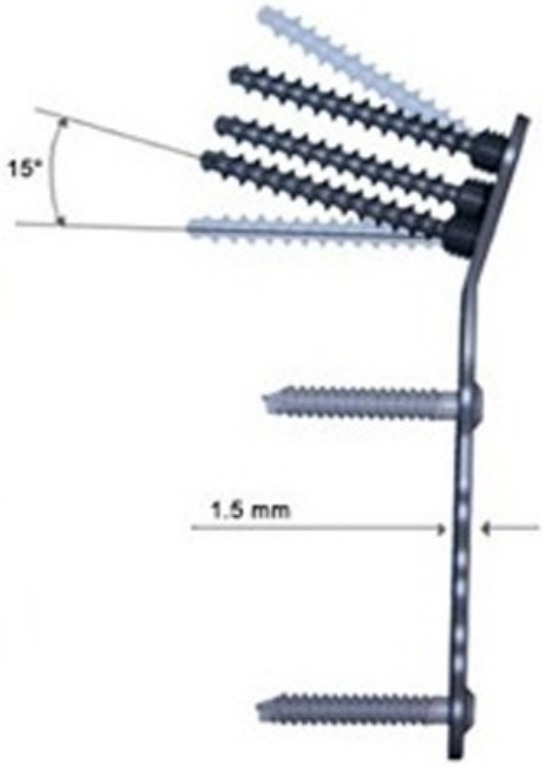

Fig. 2: Angle-stable fixation system: the screws can be inserted at an angle of up to 15°, (reproduced, with modifications, from: www.chirurgiadellamanobrescia.it).

Although contraindicated for patients with a poor general condition, surgery is almost mandatory for young patients, in order to prevent deformities and functional deficits [17]. The volar surgical approach is currently the method of choice for most surgeons due to the fact that it provides more space for the plate and the pronator quadratus muscle can be used to cover the fixation device, avoiding direct contact between the flexor tendons and the device, thereby protecting the tendons from friction irritation. Recent studies have shown that the results of the volar approach are comparable to those obtained with the use of dorsal implants in cases with dorsal displacement of fracture fragments. It is important to respect the correct guidelines for the positioning of the plate: it should be placed within the pronator fossa, and not cross the so called "watershed line" to ensure that there is no contact with the flexor tendons, while providing support for the volar margin of the radius (shelf action). If the fixation implant is placed in a more distal position, the screws need to be oriented proximally to avoid inadvertent articular penetration; guide wires can be applied to the appropriate holes to establish correct screw positioning [18]. When dealing with a fracture with articular involvement, particular attention should be paid to reduction, especially when

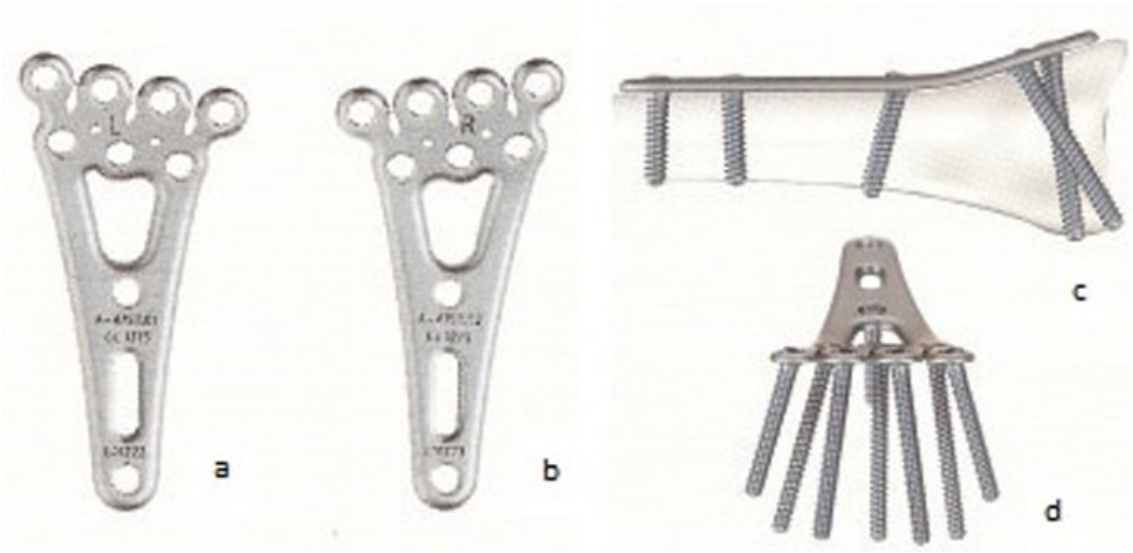

Fig. 3: Footprint shape plate; for the left distal radial epiphysis (fig. 3a), for the right radius (fig. 3b), lateral projection with screws (fig. 3c), frontal view with screws (fig. 3d), (reproduced, with modifications, from: www.extera.com).

medial *die punch* fragments are present. Volar fragments are easy to address with the standard volar approach, but in the presence of medial dorsal fragments, the extended flexor carpi radialis (FCR) approach is performed through the volar incision. The dorsal aspect is accessed by releasing the radial septum and pronating the proximal radius to expose the area of interest. After reduction is accomplished and verified by fluoroscopy, a suitable fixation plate is selected. In fractures with both volar and dorsal comminution, a double (volar/dorsal) incision can be performed for the reduction and, if necessary, double plating can be carried out in patients with a good bone density [19]. After treatment, the wrist is immobilized with a splint, and monitored for eventual secondary displacements and fracture consolidation. This approach enables an early mobilization as soon as sutures are removed. Functional recovery is usually obtained by four months to one year from the injury with an appropriate rehabilitation program. This should involve a global approach for the entire limb, aimed to reduce swelling and maintain tissue tropism, as well as to recover the normal range of motion and avoid joint stiffness; a gradual recommencement of everyday activities is also important [20]. Potential complications include malunion, nerve damage, infection, complex regional pain syndrome (CRPS), also known as Sudek's atrophy or reflex sympathetic dystrophy (RSD), tendon lesions, delayed consolidation and pseudoarthrosis, as well as post-traumatic arthritis.

The following is a brief description of the most commonly used fixation devices:

Variable Angle LCP Two-Column Volar Distal Radius Plate: because of its design, this device can be placed in a very distal position: low plate and screw profile, in addition to the rounded edges, reduce the risk of soft tissue irritation. The device offers a locked construct ensuring a correct stabilization of the styloid process and offering support to the lunate facet. The oblong holes allow longitudinal adjustment, and guide wire can be used for a temporary fixation. Due to the specific design of the screw head, the screws can be applied with an angle of 15 degrees. The plate may appear to have little contact with the bone surface; this is due to the stable fixation between the screws and the plate, helping to avoid periosteal revascularization and thus aiding callus formation [21].

VariAx Distal Radius Locking Plate System: the transversal plane of this plate has two rows of screws, while the volar plane is large, offering an optimal support for the cortex; specific plates are available for the right and left wrist for an optimal stabilization of the radial styloid apophysis. The contour of the plate allows for a positioning that at the same time offers support to the medial volar margin of the distal radius and respects the watershed line. Locking

or compression type pegs or screws are available for this system, including locking pegs, full or partial thread, with a diameter ranging from 2.0 to 2.7 mm, depending on insertion location (stem or head). Screws can be inserted at a variable angle of up to 15 degrees [13].

DVR-A Volar Plating system: characterized by an anatomic design, robust stem and contoured distal surface, with a wide head offering a good degree of support to the ulnar margin, while the radial side is thinner and smaller. The shape is contoured to match the watershed line of the distal radius, minimizing flexor tendon irritation. This device offers a double-tiered screw/peg support arranged in intersecting rows, providing a three dimensional support scaffold for the articular surface. The radial peg angle allows the fixation of the radial styloid. Three types of pegs/screws can be used with this system: cortical, threaded or smooth (distal: 2.5 mm; stem: 3.5 mm). The fixed-angle guide wires used for the positioning and temporary fixation are perfectly aligned with the final screw/peg angulation, making wire replacement and screw placement easier [22].

Contours VPS (2.0-3.5 mm): anatomic with a curved distal end, this device is designed to accommodate the broad anatomical variances between patients (including volar radial tuberosity, watershed line and lunate facet prominence). The screws are inserted into the subchondral bone, considered the densest bone in this region even in patients with osteoporosis. Lateral fluoroscopy can be used to assess any suspected penetration into the articular surface. The plate can be completely covered by the pronator quadratus muscle. The self-tapping screws are available in different sizes ranging from 3.5 to 2.0 mm for different types of bone fragments and radial diaphysis. The plate features a large central hole that can be used as a graft window if necessary.

Aptus Radius 2.5 mm: this fixation system is characterized by a low profile plate (1.6 mm) and a consistent screw diameter (2.5 mm). The plate has a distinct footprint shape, and the device is designed to support the medial distal margin and contour the watershed line. The multidirectional screw holes allow subchondrial and para-articular screw placement, with additional screw holes on the stem of the plate. No screws are inserted in the metaphyseal area, offering the possibility to insert bone crafts through the graft window. The screws can be positioned in a 15 degree angle (fig. 3a, b, c and d).

Acu-Loc (2.3-3.5 mm): anatomically angled design with an elevated portion for the lunate facet and a flatter portion in correspondence with the radial styloid process. The radial margin of the plate is contoured to match the volar radial tuberosity and ridge. The screws for the stem and the epiphyseal area are of different diameters; locking or non-locking screws can be used. The distal screws, specifically targeting the radial styloid apophysis are angled forward and can be targeted by using a special guide. The final screw placement is similar to that of the DVR-A plating system.

Fig. 4: Displaced, comminuted fracture, with articular involvement. Reduction and fixation is carried out through a volar incision, by fixing the distal fragment with a K-wire through the styloid process and using a metallic angle-stable plate and cortical screws.

Personal Experience

In the period between January 2010 and October 2011, 76 patients with distal radius fractures were treated in the Orthopedic and Traumatology Unit of the Polyclinic of the University of Palermo. 18 of these, or about ¼, were fitted with angle-stable volar fixation plates. Patients with B or C type fractures (AO), who were aged between 17 and 71 (mean age 48) were included in the study. Active mobilization was started almost immediately after surgery. All patients underwent clinical and radiographic follow-up at predetermined intervals. There were no complications such as infections or metal allergies or sensitivity leading to plate removal, and all fractures consolidated uneventfully with no cases of loss of reduction, or clinical or radiologic signs of failure (fig. 4, fig. 5).

Fig. 5: Comminuted, intra-articular fracture with dislocation-diastasis of the proximal carpal row. Reduction and fixation by metal plate are carried out through a volar incision. The scapholunate dissociation is reduced by percutaneous K-wire.

Conclusions

The introduction of fixation plates with variable angle locking screws has made internal fixation the recommended form of treatment not only for intra-articular fractures, but also for unstable and stable metaphyseal fractures, when a faster functional recovery is desired [23]. Consequently, treatment algorithms that were in use until a few years ago have been modified. Fixation plate design has progressively evolved to fit the anatomy of the radius better, and distal radius fracture fixation is now possible with a single volar incision using the *Fragment Specific Fixation System* for radial styloid process, or volar or dorsal *die punch* fractures. Some plating systems have proved to be more suitable for the fixation of articular fractures, and some have the benefit of having specifically angled or contoured extremities, and optimized screw positioning and angulation [24]. Some systems are best suited for the volar approach fixation of dorsal-ulnar *die punch* fractures, while others are recommended for more proximal fractures. It is no longer considered acceptable to treat all simple fractures by conservative methods that do not guarantee a quick recovery and are often poorly tolerated by the patient. If a fast functional recovery is desired and/or required, and the patient is aware of, and willing to accept the risks involved in the surgical procedure, we should be able to meet these requests by offering a reliable fixation with an adequate angular stable plate according to the type of fracture. It should also be noted that some plates have an additional benefit: they do not necessarily need to be removed.

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