ASPECTS OF CURRENT MANAGEMENT

A revolution in the management of fractures of the distal radius?

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The recent development of locking-plate technology has led to a potential revolution in the management of fractures of the distal radius. This review examines the evidence for pursuing anatomical restoration of the distal radius and the possible advantages and pitfalls of using volar locking plates to achieve this goal. The available evidence for adopting volar locking plates is presented and a number of important and, as yet unanswered, questions are highlighted.

Fractures of the distal radius are common and account for a considerable proportion of all attendances at fracture clinics. Despite this, their management remains a matter for debate. Although fractures of the distal radius have been the subject of much research, the absence of large, prospective outcome trials of the different methods of treatment is surprising given the number of patients available for study.

Recently, the development of locking-plate technology has changed the way in which many fractures are managed. A locking plate has a number of theoretical advantages over the conventional non-locking implant, not least of which is improved fixation in osteoporotic bone. No other area of fracture management has been affected as much by the emergence of technology as the treatment of fractures of the distal radius. This has generated renewed interest in the treatment of these fractures and an increase in the production of a variety of specific locking devices. This abundance of implants is driven by the manufacturers who envisage a huge new market, however, there is little evidence-based research to guide our use of these devices.

Is anatomical restoration of the distal radius necessary to achieve good long-term function?

This fundamental question has been debated but as yet remains unanswered. The assumption that outcome is improved by the restoration of normal anatomy underpins the growing enthusiasm for volar plating of fractures of the distal radius.

For many other intra-articular fractures, the principle of stable anatomical fixation and early mobilisation is well-established and universally accepted. Why this philosophy has developed more slowly for the distal radius is unclear, but perhaps the difficulty in restoring the anatomy of this complex joint has dissuaded surgeons from pursuing an anatomical reduction. Since the earliest descriptions of fractures of the distal radius, the assumption has been made that a good result will be achieved whatever the appearance of the reduction. This may still be the case in most fractures which occur in elderly, low-demand and osteoporotic patients, but there is a clear distinction between this group and those with higher demands, bearing in mind that these may not necessarily be younger.

A number of clinical and biomechanical studies have demonstrated the advantages of restoring normal anatomy, but the number of studies which have used validated patient-derived outcome measures has been few and there are no long-term prospective comparative studies of alternative methods of treatment to guide our management. Földhazy et al recently reported the nine- to 13-year follow-up of fractures of the distal radius which had been treated without surgery. They concluded that a number of patients continued to experience some impairment of hand and wrist function. The patients’ perception of this impairment was not recorded and whether the outcome could have been improved upon by surgical intervention is not known.

The threshold for acceptable extra-articular malunion has not been defined. Malunion with radial shortening has been reported most commonly to be associated with a poor outcome as defined by surgeon-based
outcome measures such as those of Gartland and Werley. The influence of ‘moderate’ (0 mm to 8 mm) radial shortening has been questioned. Barton, Chambers and Bannister found no correlation between moderate shortening and outcome, as assessed by the Patient Related Wrist Evaluation at a mean follow-up of 29 months.

It is generally accepted that persistent irregularity of the articular surface predisposes to the development of radiologically-identified degenerative changes, but the relevance of such changes is debated. There does not appear to be a clear correlation between radiological degenerative change and a poor clinical outcome, at least in the medium term. A series of patients studied by Catalano et al with a mean follow-up of seven years was re-evaluated at 15 years. Although the arthritic change as assessed by radiography and CT had progressed, the only correlation with arthritic change was an insignificant reduction in wrist flexion. Furthermore, a study recently published by Forwood, Davis and Sithole, in which 106 young adults under 40 years of age were retrospectively reviewed at a mean of 38 years, showed no difference in the Disabilities of the Arm, Shoulder and Hand (DASH) scores from population norms and minor (less than 10%) functional impairment as measured by the patient evaluation measure. They also found no measure of extra-articular malunion which was related to either the patient evaluation measure or DASH score, and were unable to identify any thresholds of malunion beyond which function was clearly worse.

Despite the growing enthusiasm for the anatomical reduction of fractures of the distal radius, there remains some doubt as to whether patients will be better served, or more satisfied, with this approach in the long term. Anecdotally, despite the large numbers of patients with a fracture of the distal radius, those requiring intervention for long-term unsatisfactory results is small.

Decisions on treatment
Undisplaced fractures are usually stable and may be adequately treated in a plaster cast. Most fresh displaced fractures can be reduced satisfactorily using the principles of ligamentotaxis. It is more difficult to predict the likelihood of re-displacement, and therefore the need for stable fixation. Lafontaine, Hardy and Delince identified five predictors of instability: a patient over 60, an intra-articular fracture, dorsal comminution, dorsal angulation of more than 20° and an associated ulnar fracture. Mackenney, McQueen and Elton have recently developed formulae for predicting the radiological outcome and have produced a prospective method for quantifying the risk of instability, although this remains unvalidated and too complex for use in clinical practice.

There are several options for the operative treatment of unstable fractures. These include the use of Kirschner (K-) wires with a plaster cast, external fixation (bridging or non-bridging, with or without additional K-wires) and open reduction and internal fixation. There is also some evidence to suggest that arthroscopy of the wrist may help in the management of intra-articular fractures. The options for open reduction and internal fixation include dorsal or volar fixation (or both) and the use of locking or non-locking implants, but without a clear evidence base to guide the choice of technique. A Cochrane Review concluded that the 48 randomised trials of treatment choices available in early 2003 “do not provide robust evidence for most of the decisions necessary in the management of these (distal radius) fractures”. Furthermore, the authors concluded that: “it is also unclear whether surgical intervention of most fracture types will produce consistently better long-term outcomes”. More recent Cochrane reviews which investigate the evidence for external fixation and percutaneous pinning were also inconclusive.

If one accepts the premise that anatomical restoration is desirable, the development of the volar locking plate has added a new implant with which to pursue this goal. They are now widely used, both to stabilise fractures which could be reduced in a closed manner and therefore would be amenable to a combination of K-wires, plaster, and external fixation, as well as those fractures which could not be reduced by closed techniques and would have required treatment using other methods of internal fixation.

Why volar locking implants?
Most fractures of the distal radius are dorsally-angulated and displaced, which makes the dorsal surface the most appropriate for buttress plating as it counteracts the deforming forces. It is also subcutaneous and easy to access surgically. However, the dorsal aspect of the distal radius is not the ideal site for a plate. There is little soft-tissue cover and the bone is covered by the extensor tendons and their sheaths. Since the dorsal radius is convex, the tendons rub against any implant. Communion of the dorsal cortex adds to the complexity of the operation and dorsal scars are less well-tolerated by the patients. Consequently, while studies of dorsal plating showed excellent results in terms of reduction of the fracture, irritation of the extensor tendons leading to tenosynovitis and attrition rupture was a widely reported problem, particularly with the more bulky implants or those which required intra-operative cutting to fit. Loss of palmar flexion due to dorsal scarring was also a problem. Early removal of the metalwork did not necessarily prevent such complications.

The design of dorsal plates has since been improved; the profiles of the plates are pre-contoured to reduce the need for cutting or shaping; the screws fit flush to the plate and locking technology has imparted angular stability. The use of modern dorsal plates improved the clinical results and reduced the number of complications. Simic et al reported no problems with the extensor tendons in a series of 50 cases in which such plates were used.

The volar buttress plate has long been established as the standard treatment for fractures with volar angulation. The development of locking plates allows fixation of fractures...
with any direction of displacement through a volar approach, and the implant is placed on the tension side of the fracture.

There are several theoretical advantages to approaching and fixing the radius through a volar approach: more space is available, the flexor tendons are further from the bone and pronator quadratus is interposed. The volar cortex is typically less comminuted, which makes reduction of the fracture easier. Volar scars are better tolerated as they are less obvious and the blood supply to the radius is less likely to be disturbed. In addition, implants with angular stability make it easier to reduce the fracture by fixing it to the distal fragment first, before fixation to the more proximal fragment.

**Use of volar locking plates**

More than 30 designs of volar locking plate are now available. There are generally two main principles of design: fixed-angle and polyaxial locking. With fixed-angle locking, the screws or pegs are inserted into the plate at a fixed angle, usually by a threaded screw head which engages a thread in a screw hole in the plate. Typically this type of plate must be applied in a specific position on the radius, and the angles of the fixed pegs or screws are designed to provide subchondral support and stabilisation of the specific fragments of the fracture. The concept of the ‘watershed line’ has guided the design of the fixed-angle plate. The distal edge of the concave surface of the volar distal radius is marked by a transverse ridge or watershed line. Distal to this line the bone slopes dorsally and gives rise to the attachment of the volar wrist capsule and volar carpal ligaments. The plate must not project beyond this line to avoid coming into contact with, and injuring, the flexor tendons.

Polyaxial locking plates allow variation in the angle of insertion of each screw, which allows the surgeon to respond to any variation in the normal bony anatomy and to target specific bone fragments. Furthermore, the position of the polyaxial plate does not have to be fixed. Some plates have a single row of screws/pegs, while others have two or more intersecting rows. The role and relative merits of using pegs or screws has not been clearly defined. Pegs have a larger core diameter and are likely to resist bending stress better than screws, however, screws may provide better grip on individual bone fragments. Partially-threaded screws can theoretically stabilise coronal fracture fragments.

The biomechanics of the different volar locking implants have been studied in fracture and osteotomy models. Koh et al cyclically loaded ten different designs of volar locking plate and concluded that all had sufficient stability to allow early mobilisation. However, there is little available clinical research on which to base a decision regarding the choice of design, and typically this decision is based on the preference and familiarity of the surgeon, the cost of the implant and the extent of marketing by manufacturers.

Typically, acute, even displaced, intra-articular fractures can be reduced indirectly. It is as the healing process progresses and the fracture haematoma becomes organised that the fracture becomes increasingly difficult to reduce. Orbay popularised the extended flexor carpi radialis approach, in which the brachioradialis is released and the radial shaft pronated away from the distal fracture fragments. This allows debridement of the haematoma from within the fracture, before reduction and fixation.

**Clinical experience and outcomes**

Several uncontrolled case series all report good to excellent results with a variety of volar locking plates. Chung et al prospectively assessed 87 patients and found that their Michigan Hand Outcomes Questionnaire scores approached normal after six months and had improved little more by one year. There are few comparative studies, and these suffer from being retrospective, having short follow-up or a small numbers of cases. Therefore definitive information is not yet available.

From the existing literature it is clear that volar locking plates can be used successfully to stabilise both intra-articular and extra-articular fractures and to allow early mobilisation. However, the use of locking plates is not without complications. Arora et al reported an overall rate of complications of 27% in 114 patients and Rampoldi and Marsico reported a rate of 8% in 90 patients. Some complications can be attributed to the inevitable learning curve encountered with a new implant, while others are implant-specific.

The extensor tendons are not immune from injury by volar plates and irritation and rupture of the extensors form a significant proportion of the reported complications. For example, they comprised 20% of the complications reported by Arora et al. This is most likely to be a result of failure to appreciate the trapezoidal shape of the distal radius, so that screws which appear to be within the bone on the lateral view may be penetrating the cortex dorsally and injuring the extensors. The flexor tendons are also at risk from volar plating and formed 29% of the complications in the series reported by Arora et al. Most complications involving the flexor tendons can be attributed to incorrect placement of the plate, in failure to appreciate the watershed line and to anatomically abnormal tendons. Despite this, Klug, Press and Gonzalez reported a case of rupture of flexor pollicis longus in a patient with normal anatomy and a correctly positioned implant.

Because the distal articular surface of the radius cannot be seen from the volar approach without disrupting the volar radiocarpal ligaments, placement of screws and pegs into the subchondral bone outside the joint depends on a clear knowledge of the three-dimensional anatomy of the articular surface of the distal radius and careful intra-operative imaging. The use of fixed-angle locking plates may increase the risk of inadvertent penetration of the joint. If the plate is placed too distally or if the fracture is not reduced anatomically, the predetermined direction of the screws will inevitably result in penetration of the joint.
Placement of intra-articular screws after volar plating of the distal radius has been reported.\textsuperscript{54}

**Are locking plates a revolution?**

Since the first reports of volar locking plates,\textsuperscript{60} the wave of enthusiasm for these devices has continued unabated. Many case series have shown that they are effective devices for fixation of the fracture. There has been much interest in the volar approach to the distal radius and as a result the standard approach to the distal radius through the bed of flexor carpi radialis has been refined.\textsuperscript{61} Subchondral placement of implants has focused attention on accurate imaging and improved the understanding of the three-dimensional shape of the distal radius.\textsuperscript{62,63}

The locking plate appears to have the advantage of reliable fixation in osteoporotic bone which facilitates early mobilisation. The volar approach allows anatomical reduction of intra-articular and extra-articular fractures and a locking plate enables this reduction to be maintained.

Other advantages include ease of reconstruction of the comminuted irreducible intra-articular fracture, and in delayed reconstruction of intra- and extra-articular fractures. However, as with all new implants, natural enthusiasm can lead to the extension of their use into areas which are less obviously justifiable. Early fixation of minimally-displaced or undisplaced fractures, even in elderly patients, may be warranted on the grounds of a potential earlier return to self-care, work and sport. This has to be balanced against the potential hazards of the procedure and the considerable cost of the implants. There is a risk that essential skills in the non-operative management of fractures of the distal radius will be lost. The economic impact of volar locking plates is likely to be significant but has yet to be assessed.

**What questions remain?**

There are a number of important unanswered questions which should temper any enthusiasm for fixing fractures of the distal radius with volar locking plates. Do these plates offer any definite advantage over traditional methods in terms of the long-term outcome? Does the early mobilisation allowed by volar locking plates improve outcome? What is the cost of the procedure and does the cost of the surgery and the implant balance any earlier return to normal function? Is there a place for fixing simple, even undisplaced, fractures in elderly patients to allow a more rapid return to full function? On-line clinical trials registries such as ClinicalTrials.gov\textsuperscript{64} and www.who.int/trialsearch\textsuperscript{65} reveal several current and planned studies which may answer some of these questions in the future. The fundamental debate about the long-term relevance of intra- and extra-articular malunion is, however, unlikely to be resolved.

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**References**