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EARLY EXPERIENCE WITH THE TRIMED FRAGMENT-SPECIFIC FRACTURE FIXATION SYSTEM IN INTRAARTICULAR DISTAL RADIUS FRACTURES

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This paper reports the results of fixation of intraarticular fractures of the distal radius using the TriMed fragment-specific fixation system by surgeons early in their experience with the system. A consecutive series of 22 AO types C2 and C3 fractures in 21 patients were internally fixed with the system. Restoration of articular congruity to less than 2 mm was possible in 20 fractures. At a minimum of 6 months follow-up, mean volar and radial inclination were 8° and 25°, respectively, with no loss of reduction. The patients had a mean of 50° flexion, 63° extension and a pronation–supination arc of 149°. The mean subjective Patient Rated Wrist Score was 20. Our complication rate was comparable to other published series despite long operating times. Therefore, we commend the system as a powerful tool to treat these difficult fractures but acknowledge the significant learning curve.

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The management of distal radius fractures remains an unresolved issue nearly two centuries after Abraham Colles description of this fracture in 1814. This is particularly true for intraarticular distal radius fractures. Treatment methods for these complex fractures include management in plaster, percutaneous pin fixation, open reduction and internal fixation and external fixation, often in combination, with or without arthroscopic assistance (Fernandez and Wolfe, 2005).

Long term reviews of distal radius fractures have shown poorer results with intraarticular fractures, particularly those with persistent incongruity (Kopylov et al., 1993). Therefore, irrespective of the treatment modality, the aim of management should be the anatomical restoration of the radiocarpal and radiulnar joints if possible (Fernandez, 2000). The possibility of achieving this goal is dependent on the soft tissue injury, comminution of the bone, the equipment available and the skill of the surgeon. With the introduction of the TriMed fragment-specific fixation system (TriMed Inc.,Valencia, CA, USA) separate fragments of the fracture can be individually stabilised to try to achieve anatomical restoration through limited volar and dorsal approaches, with good results (Konrath and Bahler, 2002). Biomechanical testing has shown this system to provide greater stability in comminuted fractures when compared to augmented external fixation (Dodds et al., 2002), supporting a programme of early active mobilisation. However, the system can be daunting to the unfamiliar, with a lengthy learning curve (Medoff and Kopylov, 1998).

The aim of this paper is to describe our early experience of the TriMed system following its introduction in 2001. As a tertiary centre, a significant proportion of our caseload consists of comminuted intraarticular fractures, types C2 and C3 in the AO classification (Müller et al., 1990) and we describe our results in these patients early in the surgeons' learning curve.

PATIENTS AND METHODS

This study is a retrospective analysis of a consecutive series of patients who underwent open reduction and internal fixation of intraarticular distal radius fractures using the TriMed system at the Princess Alexandra Hospital, Brisbane, in a 1 year period to August 2002. Our indications for operative fixation include, and remain, those fractures that are open, unstable, have a loss of volar tilt and radial inclination of more than 10° and those that demonstrate intraarticular displacement, or steps, of more then 2 mm. Those with intraarticular fractures, AO type C2 and C3, which were more than 6 months post surgery, were selected for the study group (Fig 1).

The only exclusion criteria were patients under the age of 16 years and those with metaphyseal bone loss that required segmental grafting.

In the study period, a total of 30 consecutive distal radius fractures were identified in 27 patients. All were treated with the TriMed system. Of these, 22 fractures in 21 patients were classified as AO types C2 (ten fractures) and C3 (12 fractures), all had intraarticular displacement, or steps, of greater than 2 mm. These 30 fractures in 27 patients formed our study group.

The operating surgeons were a mixture of Upper Limb Fellows and Consultant Hand Surgeons. Each had undergone training at specific workshops to familiarise themselves with the TriMed system but none

Fig 1 (a)–(d) Plain X-ray and CT images of a C2 type intraarticular distal radius fracture.

had performed more than 12 procedures. The decision on the implants used was made pre-operatively, based on CT scans of each wrist, and intraoperatively by the operating surgeon.

Operative technique

The surgical technique is based on the limited volar radial and dorsal approaches described by Leslie and Medoff (2000). General anaesthesia, an arm tourniquet and intraoperative fluoroscopy is used in each case. The fracture is gently manipulated with closed traction. A 5 to 6 cm longitudinal incision is then made radial to the radial artery. The superficial branches of the radial nerve are preserved in the skin flaps and the first dorsal compartment partially released proximally to allow retraction of the tendons. It is important to preserve the distal portion of the first compartment adjacent to the tip of the radial styloid. The insertion of brachioradialis tendon is identified and released from the radius to reveal the radial styloid. This is a crucial step in the procedure in sub-acute fractures as brachioradialis exerts a strong deforming force that prevents accurate reduction. If volar exposure of the radial column is required, the pronator quadratus is elevated off the distal radius to expose the volar distal radius. The dorsal radius is exposed through a longitudinal incision between the third dorsal and fourth compartments. Release of the extensor pollicis longus tendon and subperiosteal elevation of the fourth dorsal compartment is occasionally necessary in more complex fracture patterns.

Under direct vision and fluoroscopy, the radial styloid is provisionally reduced and held with a 0.045 in K-wire. The articular fragments may be visualised and manipulated through the fracture line in combination with indirect reduction techniques using intraoperative fluoroscopy. An arthrotomy is avoided if possible, as this may have an adverse effect on recovery of flexion. Depending on the pattern of the fracture, stabilisation of the specific volar, dorsal and articular fragments may be with any combination of wireform buttress pins and clamps. The radial column and dorsoulna column can then be stabilised with pin plates. The final reduction is confirmed under image intensification and the range of movement of the wrist and stability of the distal radoulnar joint (DRUJ) checked. The decision on

whether to use artificial bone graft (Norian SRS. SRS; Norian, Cupertino, CA, USA) is made by the operating surgeon, depending on the size of the metaphyseal defect. Bone graft can easily be introduced into the metaphysis of the restored wrist through a small window on the radial border of the radius, under what was the insertion of brachioradialis. A bulky padded dressing is then applied, but not a plaster.

Our standard postoperative regimen involves reducing the bandages on the first postoperative day and commencing active range of movement exercises under the supervision of a Hand Therapist. A thermoplastic resting splint is provided to the patient to aid in activities of daily living and removed for hand and wrist range of movement exercises five times daily. This splint is weaned over a period of 6 weeks and strengthening exercises started.

Patients underwent objective clinical assessment by a hand therapist, radiological assessment by two surgeons and completed a subjective outcome questionnaire at a minimum of 6 months from surgery. Clinical evaluation took the form of range of motion (dorsal midline) measurements and grip strength measurement using a Jamar Hand Dynamometer (Clifton, NJ, USA) set on the second position. Comparison was made to the uninjured side in unilateral injuries.

Radiological assessment of the accuracy of the initial articular reduction and restoration of volar and radial inclination was performed and compared to the X-rays at follow-up.

A validated subjective evaluation was made using the Patient Rated Wrist Evaluation (PRWE) (MacDermid et al., 1998). The PRWE is a region specific, self-report instrument designed for wrist and scaphoid fractures. It consists of five pain and ten function scores with a total score out of 100, with lower scores representing better outcomes.

RESULTS

The average age of the patients was 32.3 (range 18–58) years and the mechanism of injury was a simple fall in three, fall from a height in six, a crush injury in one and a motor vehicle accident in 11 patients, reflecting the high energy nature of these injuries. The average duration between injury and surgery was 14 (range 5–24) days. Five of the cases had surgery performed at least 3 weeks after the injury. This long delay was due primarily to the tertiary referral nature of our unit, but also reflects the logistics of transfers over long distances in our state of Queensland, Australia.

Five surgeons performed all procedures, with 17 done by Hand Fellows of a training grade. With respect to the implants used, every patient had a radial and ulnar pin plate inserted. In addition, nine patients had a volar buttress pin, five a volar buttress plate and eleven had volar and/or dorsal wireform clamps. In total, seven patients had at least four implants inserted. The average duration of the operations, from commencement of the anaesthetic until the patient left the theatre, was 171 (range 96–236) minutes. Nineteen patients had Norian SRS bone substitute (Norian SRS. SRS; Norian, Cupertino, CA, USA) used to fill the metaphyseal defects. No additional method of fixation was used and no patient had a plaster applied postoperatively.

There were several postoperative complications. Four patients complained of transient paraesthesiae in the median nerve distribution but these settled in all four within 1 week. One patient developed chronic regional pain syndrome (CRPS) Type 1 (syn. Reflex Sympathetic Dystrophy; Algodystrophy) and, despite intensive hand therapy and pain management, had a poorer result. One patient had an unstable DRUJ immediately postoperatively which was successfully treated in a supination splint for 4 weeks. Another developed what appeared to be avascular necrosis of part of the ulnar column. Two patients had implant removal during the follow-up period: one for clicking with forearm rotation and the other for profound stiffness. Both improved following removal of the implants. There were no instances of wound breakdown or infection. There were no patients who were felt to have intrinsic carpal ligament injuries, either before or after fixation, on radiological grounds, nor clinically, at the end of the review period.

All but one patient were followed to radiological union. This patient returned to his home town for local review and did not attend our unit again. Therefore, his immediate postoperative radiographs were assessed for adequacy of reduction but he has, otherwise, been excluded from all follow-up analysis. The mean follow-up was 10 (range 6–25) months. Clinical review and questionnaire assessment were performed at the last outpatient visit. A summary of the results is reported in Table 1.

Analysis of the immediate postoperative X-rays showed that two fractures had not had the intraarticular component reduced to less than 2 mm displacement and two had had a non-anatomic reduction of the volar–ulnar corner of the fracture. The radial inclination was restored to a mean of 26° (standard deviation 4.7) and volar inclination to a mean of 8° (standard deviation 5.0). Reviewing the X-rays taken at final follow-up at a mean of 8 months (range 6–25) showed no significant loss of reduction compared to the immediate post-operative images (Figs 2 and 3).

DISCUSSION

The management of intraarticular fractures of the radius represents a difficult and challenging problem for the surgeon. These injuries often occur in young people as a result of high energy trauma with significant articular and metaphyseal comminution. Some authors have found that the most important factors affecting

Table 1—Summary of the clinical assessment and PRWE scores of 21 fractures in 20 patients

	Mean (*SD*)	*Range*
Active flexion (°)	50.8 (13.7)	25–68
Active extension (°)	62.4 (9.7)	46–82
Flexion/extension arc (as % of uninjured side)[a]	76.2 (11)	51–93
Active supination (°)	75.0 (18.6)	12–106
Active pronation (°)	75.9 (13.4)	34–92
Pronation/supination arc (as % of uninjured side)[a]	86.8 (13.6)	56–109
Grip strength (Kg)	37.3 (12.1)	3–52
Grip strength (as % of uninjured side)[a]	84.4 (22.7)	21–131
PRWE score	20.5 (17.3)	2–68

[a]Excludes patient with bilateral wrist fractures.

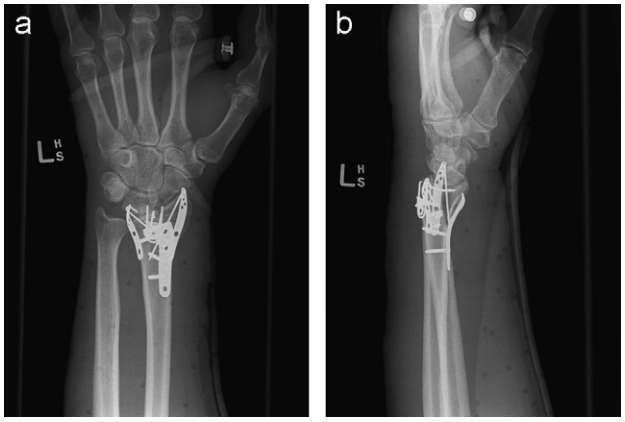

Fig 2 (a) and (b) Immediate postoperative X-rays of fixation with radial and dorsal pin plates, dorsal wireforms and a volar plate.

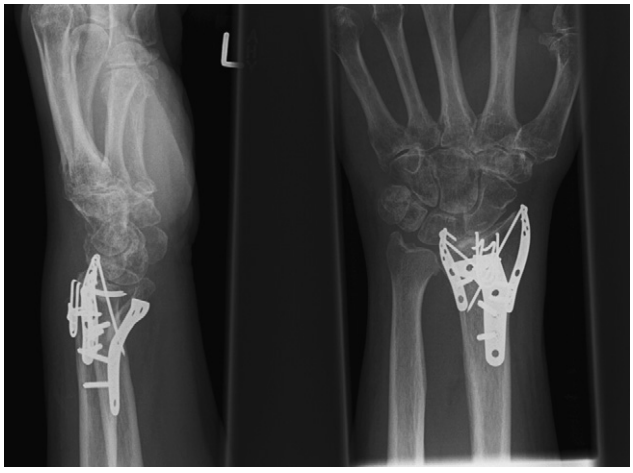

Fig 3 Plain X-rays at 8 months after surgery showing healed fracture and maintenance of reduction.

functional outcome and radiographic evidence of degenerative change are intraarticular steps or gaps (Knirk and Jupiter, 1986; Trumble et al., 1993). However, there is uncertainty as to what is an acceptable step, with some evidence suggesting that the size of the step is less relevant than the presence of one, and that small gaps may not influence outcome at all (Gliatis et al., 2000). The same authors have found that loss of the normal radial inclination is also associated with poorer functional outcome. Therefore, the ideal of anatomical reduction must be balanced against the reality of achieving this in the face of significant bony comminution and soft tissue injury (Fernandez, 2000).

We believe that the fragment-specific fixation of the TriMed system allows the surgeon to tailor the implants to the fracture pattern as required. Not only can the wireforms aid the reduction of the fractures, but they are sufficiently stable to maintain the reduction until union. In our series, surgeons early in their experience with the system have been able to restore the articular margin in 20 of 22 patients and restore the volar and radial inclination to a mean of 8° and 26°, respectively, with no loss of reduction. This is comparable to other published series of the TriMed system (Konrath and Bahler, 2002), external fixation (Krishnan et al., 2003) and internal fixation (Campbell, 2000; Ring et al., 2004).

A recent metaanalysis of the published literature compared internal and external fixation of unstable distal radius fractures (Margaliot et al., 2005). The pooled estimates for wrist flexion were 55.7° and 52.4°, wrist extension 55.4° and 59.3°, pronation 84.4° and 78.5° and supination 75.0° and 79.3° for external and internal fixation, respectively. The range of movement in our series is comparable to these results. One of the advantages of the using the TriMed system was that we were able to achieve stable intraoperative fixation of all the fractures in our series. Although one patient required a static splint for an unstable DRUJ, no patient required supplementary stabilisation with an external fixator, or was immobilised in plaster to protect the fixation. The patients were, therefore, able to commence an active range of movement exercise programme from the first postoperative day.

We feel the duration of the operations was too long in our series, with the longest procedure taking 236 minutes. This was, in part, due to our relative inexperience with the system and almost certainly contributed to the transient median nerve paraesthesiae in four of the patients. However, the cases in our series were all complex intraarticular fractures and longer operative times should, perhaps, be expected. In none of the articles referenced in this paper has the duration of the procedures been recorded, so we are unable to compare our experience with that of others. Recent experience in our unit suggests that most procedures by the Hand Fellows now take under 140 minutes as not only the surgeons but the theatre staff have become familiar with system. Procedures by experienced members of our unit routinely take less than 120 minutes. The significant delay between the injury and fixation of the fractures may also have played a part in the long operative durations. Four of the fractures were more than 4 weeks postinjury. At this stage, the soft tissue is indurated and reduction difficult as excision of fibrous tissue and early callus was required. Also, as the fractures had often displaced within the plaster, there was always significant shortening, particularly of the radial column. As brachioradialis is a major deforming force on the radial styloid it must always be released to allow reduction (Medoff and Kopylov, 1998). Whether the long delay prior to surgery affected our outcome is unknown.

There were three major complications in our series. One patient with gross comminution developed what appeared to be avascular necrosis of part of the ulnar column. We have been unable to differentiate between the contributions of the soft tissue injury itself and the surgical intervention in causing this, but it remains the only single case in which we have seen this occur. The DRUJ instability was missed at the time of surgery, despite reduction of the sigmoid notch of the radius. The single case of CRPS Type 1 had a poor functional and subjective outcome. There is an appreciable incidence of CRPS described in the treatment of these fractures (Musgrave and Idler, 2005; Margaliot et al, 2005) and we feel that one case in 22 C2/C3 fractures is a relatively low incidence of this complication. We do not feel that changing to another form of fixation would allow us to avoid this complication in all patients.

One of the major issues with open reduction and internal fixation, particularly if dorsal plates are used, is irritation of the extensor tendons. Although two patients required removal of metalwork, none of them were for synovitis or tendon attrition and rupture, despite all patients having had some dorsal implants. In one series of volar and dorsal plating there were two tendon ruptures and 21 of 25 plates were removed (Ring et al., 2004). In another study, a randomised prospective trial comparing dorsal plating to external fixation and percutaneous fixation (Grewal et al., 2005), the randomisation was stopped early because of a 72.4% complication rate in the dorsal plating group, with five cases of tendonitis and eight of 17 patients requiring removal of the plate. The implants used from the TriMed system are low profile and do not appear to cause the same problems as dorsal plating. We note that, in both this and another series (Konrath and Bahler, 2002), removal of the implants was necessary when either pin plate or wires affected forearm rotation by being too close to the DRUJ.

Overall we have found our results obtained from internal fixation of intraarticular distal radius fractures to be satisfactory. The fragment-specific nature of the implants in the TriMed system allows the surgeon to reduce and maintain an accurate reduction of these fractures with stabilisation of all major fragments until bony union. The system is unlike other fixation methods and, as a result, there is a definite learning curve that the surgical team must go through in order to familiarise themselves with it. Nonetheless, we have shown that, even during this learning period, good anatomical reduction can be achieved and good functional outcome obtained.

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