Decision Making in the Management of Distal Radius Fractures

Kunal Kulkarni[1], Nick Johnson[1], Joseph Dias[1]

Abstract

Background: Distal radius fractures are one of the commonest orthopaedic injuries, occurring across the lifespan. They follow a bimodal incidence, occurring as low energy fragility fractures in older patients with low bone mineral density (particularly women), and higher energy fractures in younger patients (particularly boys and young men). Skeletally immature patients commonly experience different fracture patterns and may tolerate greater deviations from anatomical alignment due to the remodeling potential.

Methods: An electronic search of relevant papers and national guidelines was performed. This review considers the variation in the broad evidence base and consensus guidelines on the presentation, management and rehabilitation of distal radius fractures, providing a practical guide to the management of these common injuries. The focus is on adult fragility fractures, although differences in the management of paediatric injuries are also considered.

Results: Pain and disability are the two main concerns among patients following distal radius fractures. Management of distal radius fractures can be both non-operative, comprising casting with or without prior closed manipulation, or operative, commonly with closed reduction and percutaneous Kirschner wire fixation, or open reduction and internal fixation with volar locking plates. Overall goals of treatment are to manage pain, restore and maintain (anatomical) alignment to reduce the risk of arthritis, and to rehabilitate patients to pre-injury function.

Conclusions: The evidence base on the management of distal radius fractures is generally limited, with significant heterogeneity, and few high quality studies. Most national guidelines therefore incorporate expert consensus. The evidence challenges common practices such as prolonged immobilisation (with a focus on earlier active patient-led rehabilitation) alongside the rising use of volar locking plates. Reducing cost of care and improving the speed of rehabilitation is relevant as epidemiological studies predict a rise in the global number of distal radius fractures, secondary to a growing and ageing population, resulting in rising costs for healthcare systems and society. In addition, distal radius fractures are often deemed predictive of future fragility fractures, as part of a 'fracture cascade' and their management must therefore include proactive assessment and management of bone health and falls risk.

Keywords: Distal radius fracture, fragility, manipulation, reduction, Kirschner wire, volar locking plate, open reduction internal fixation

Introduction

Distal radius fractures (DRFs) are one of the commonest orthopaedic injuries (1).Global incidence rates range from four to 110 per 10,000 person-years(2). A bimodal distribution is observed, with lower energy fractures (commonly fall from standing height onto the outstretched hand) usually occurring in older adult patients, particularly osteoporotic post-menopausal women, and higher energy fractures (commonly sporting and motor vehicle accidents)occurring in younger patients, particularly teenage boys or young adult males(2). Patient factors (older age, female sex, fragility fracture risk factors) and environment (higher physical activity, greater motor vehicle usage, lower socio-economic status, climate) both influence DRF incidence. With a growing and ageing population, epidemiological studies predict rising numbers of DRFs (3). Management of fractures can be both non-operative, comprising casting with or without prior closed manipulation, and operative, commonly with closed

[1]Department of Orthopaedic Surgery, University Hospitals of Leicester, Leicester, UK.

Address of Correspondence
Professor Joseph Dias
Surgery, AToMS-Academic Team of Musculoskeletal Surgery, Undercroft, University Hospitals of Leicester NHS Trust, Leicester General Hospital, Gwendolen Road, Leicester, LE5 4PW
Email: jd96@leicester.ac.uk

reduction and percutaneous Kirschner wire (K wire) fixation, or open reduction and internal fixation (ORIF) with volar locking plates (VLP). (Figures 1 and 2)While there remains a significant lack of consistent evidence on many aspects of DRF management, the overall goals of treatment are to manage pain, restore and maintain (anatomical) alignment, and to rehabilitate patients to pre-injury function.(4)Skeletally immature patients commonly experience different fracture patterns and may tolerate greater deviations from anatomical alignment due to greater remodeling potential(5). This review considers the variation in the evidence and consensus on the presentation, management and rehabilitation of DRFs, providing a practical guide to the management of these common injuries. Emphasis is placed upon adult fragility fractures, which comprise the majority of DRF, although the unique fracture patterns and management of paediatric DRFs is also considered.

Material and methods

In September 2018, an electronic search of MEDLINE (via PubMed), EMBASE and the Cochrane Database of Systematic Reviews was undertaken to identify relevant articles pertaining to the management of paediatric and adult DRFs. Guidelines from the American Academy of Orthopaedic Surgeons (AAOS), British Orthopaedic Association (BOA), British Society for Surgery of the Hand (BSSH), Danish Health Authority (DHA), and the United Kingdom's (UK) National Institute for Health and Care Excellence (NICE) were also electronically searched and reviewed(6)(7,8)(9)(10). DRF were generally defined as occurring within two to three cm proximal to the radio-carpal joint, occurring at the junction where the cortical bone thins. (11, 12)Paediatric (skeletally immature) populations were defined as aged under 16 years, with adults aged 16 years or over. Search terms included: "distal radius fracture", "Colles' fracture", "Smith's fracture", "Barton's fracture", "wrist fracture", "fragility radius fracture", "paediatric distal radius fracture", "physeal radius fracture", "Salter-Harris radius fracture", "extraarticular radius fracture", "intraarticular radius fracture", "manipulation radius", "closed reduction radius", "Kirschner wire", "K wire radius", "volar locking plate", "operative radius fixation", "open reduction internal fixation radius", and "radius external fixation". Articles were shortlisted for consideration if they pertained to paediatric or adult DRF.

Initial assessment and management

Initial review should consider and document the relevant history (mechanism of injury, co-morbidities, functional baseline, hand dominance, work/activities, previous injuries, risk factors for fragility fractures or falls risk, suitability for anaesthetic if required), and focused examination (skin integrity, specific neuro-vascular examination – including sensation and motor function) (13). Open fractures should be managed as per standard protocols and availability of adjunct services (e.g. plastic surgery), with initial normal saline irrigation to remove any gross contaminants, photographs of the wound taken and securely stored, coverage of the wound with a sterile saline-soaked gauze, and appropriate antibiotics and tetanus prophylaxis administered(14).

Imaging and classification

Two-view radiographs (postero-anterior, PA, and lateral view) should always be performed, before and after any manipulation. Several parameters can be utilised to assess the integrity of the wrist joint(15). As a rule of thumb, "11, 12, 23" can be used as an aide-mémoire for average palmar inclination (volar tilt, 11 degrees), radial height (12 mm) and radial inclination (23 degrees)(15).(Figure 3)If in doubt, radiographs of the contralateral wrist can be used to evaluate individual norms, alongside assessment of ulnar variance(60 percent are ulnar neutral) and scapho-lunate angle (average 30 – 80 degrees, dependent on wrist position). Further imaging, such as computed tomography (CT) or magnetic resonance image (MRI) scanning may be helpful in certain cases (e.g. high energy injuries, evaluation of key articular fragments in comminuted or intraarticular fractures, suspected ligamentous injuries) for planning management, but are infrequently required. There are several commonly (if not always correctly) used eponyms, including Colles', Barton's and Smith's fractures. Furthermore, around 15 different classification systems exist for DRFs, with several demonstrating up to 'moderate' reliability and reproducibility at best, including AO, Frykman, Melone, Mayo and Universal (16). However, no single classification system consistently guides management, for reasons including complexity and poor inter-observer reproducibility. While their use is therefore often confined to research, they can play an important role in helping predict instability and therefore guiding management decision making(17).

Reduction goals

A significant proportion of patients with DRFs require manipulation of the fracture fragments to achieve a more anatomical position. While most reductions tend to be performed in the emergency department (ED) setting, this is often without 'live' image intensifier (II) guidance. While II guidance can undoubtedly help get the reduction right first time, no studies have directly evaluated this(7). There is no clear evidence to definitively conclude which radiographic parameters correlate with functional outcomes. However, expert consensus suggests that in the acute setting (for adult patients aged under 65 years), manipulation to obtain anatomical reduction should be achieved, with correction of any radial shortening (i.e. ulnar variance), dorsal tilt, and articular incongruence (i.e. intraarticular step, particularly over 2mm), alongside restoration of distal radio-ulnar joint (DRUJ) alignment, most important in improving functional outcomes(6, 18).(Table 1)However, for patients aged over 65 years with moderately displaced fractures, the evidence suggests that there may be no overall functional benefit to manipulation(6, 19). The ultimate goal of management should be to restore function to pre-injury levels, taking into consideration factors including patient expectations, occupation, co-morbidities, mental capacity, independence, age, compliance and fragility.

Analgesia for reduction

UK-NICE guidelines recommend the use of intravenous (IV) regional anaesthesia (i.e. Bier's block, performed by appropriately trained individuals) for the reduction of dorsally displaced DRFs in adults.(7)The improved pain relief this provides can facilitate better fracture reduction, hence NICE suggest it is reasonable for appropriate patients to wait up to 72 hours post injury for the availability of trained professionals to facilitate this form of anaesthesia for manipulation. (20)(21)(22)(23) However, haematoma block is a safe alternative that is perhaps more practical in most ED settings. Nitrous oxide and oxygen ('gas and air') may serve a useful adjunct, but should not be used in isolation as this provides inadequate analgesia. In the paediatric population, ketamine provides safe and quick sedation to facilitate fracture reduction(24).

Post-reduction immobilisation and follow up

In adults with dorsally displaced DRFs (Colles' type fractures), manipulation to an anatomically acceptable position and non-operative manipulation in plaster is acceptable provided there is no further displacement(6). Reduction should follow established techniques, commonly involving in-line traction for ligamentotaxis, followed by exacerbation of the deformity if needed to disimpact the fracture before correction(25). With limited evidence to draw firm conclusions regarding optimal post manipulation immobilisation, either a full moulded plaster of Paris (PoP) cast, a ¾ plaster slab, or a backslab are appropriate, depending on the experience of the clinician(6). In all cases, patients should be provided with advice and emergency contact information to discuss concerns. It is recommended that plasters utilise Charnley's 'three-point' moulding with the wrist in neutral flexion (rather than forced palmar flexion, which can increase carpal tunnel pressure and stiffness), paying attention to cast index (ratio of sagittal to coronal width from the inside edges of the cast at the fracture site; higher ratios are associated with redisplacement) (26, 27)(28)(29). (Figure4) We advise repeat radiographs at one to two weeks following manipulation, particularly when the fracture pattern is potentially unstable and subsequent surgical intervention may be required should there be an unacceptable degree of re-displacement(6). This recommendation is expert consensus based, and considers the increasing difficulty of surgical fixation beyond two to three weeks. Subsequent imaging should also be observed for other adverse features of instability such as the uncommon progressive scapho-lunate gap or (commonly dorsal) subluxation of the ulna, although the optimal management of these remains unclear(30). While classic orthopaedic dogma has followed the 'six-week' rule for immobilisation for non-operatively managed fractures, we advocate removal of plaster and mobilisation from four-weeks following injury. This change to practice follows evidence that earlier mobilisation correlates with improved earlier functional scores (31)(32). Patients with stable fracture patterns (particularly older patients with un/minimally displaced fractures not requiring manipulation) can be considered for either removable splints or even simple crepe bandages to encourage earlier functional recovery and resolution of wrist swelling. (31)Repeat radiographs at the time of plaster removal are not specifically required(6).

Re-displacement

While no universally agreed description exists to define 'unstable' distal radius fractures, a range of factors have been attributed to increasing the likelihood of re-displacement. These include greater initial displacement (i.e. shortening, dorsal angulation greater than 20 degrees), volar displacement, comminution, and advancing age (i.e. over 60 years); patients with these fracture characteristics therefore warrant closer follow up(6, 33). La Fontaine's 1989 criteria (dorsal tilt greater than 20 degrees, dorsal comminution, intra-articular fracture, associated ulnar fracture, age over 60 years) propose three or more features to suggest more unstable patterns with a greater likelihood of collapse(34). Similarly, Mackenney et al identified several risk factors for instability, including initial displacement, advancing age, any comminution, and positive ulnar variance (compared with the uninjured contralateral wrist) to be significant predictors of early instability (i.e. within the first two weeks)(35). Consideration of early operative fixation should therefore be given to fractures with such factors suggesting inherent instability.

Surgical fixation

Where fixation is deemed necessary (unacceptable position, unstable fracture pattern, displacement of intraarticular fragments), surgery should ideally be performed within 72 hours (intra-articular fractures) or within seven days (extra-articular fractures), so as to minimise organised haematoma formation and undue delay for patients. For fractures displacing after initial manipulation, surgery should be within 72 hours of the decision to operate(8). The decision to operate should consider all relevant patient and functional factors, the option of non-operative management, outcomes following mal-union, and the different surgical techniques available(6). There is no evidence to conclude the impact of timing of surgery on functional outcomes or complications (including pain or chronic regional pain syndrome, CRPS), although common sense dictates that patients are best served by balancing the avoidance of delay (with its associated pain and functional limitations), with availability of an appropriate surgeon and facilities. There is growing evidence to support equivalent functional outcomes (at up to four and a half year's mean follow-up) from non-operative management in patients aged over 65 years(36, 37) (38)(39)(40). Combined with the increased risks of surgery in older patients, due consideration should therefore be given to non-operative management of DRF in patients aged over 65 years. However, for adults under 65 years of age, the literature is inconclusive on whether non-operative or operative treatment is better for managing dorsally displaced fractures(6). In patients necessitating surgical fixation, K wire fixation remains an established technique for maintaining reduction post manipulation, although there is no clear evidence at present to conclude whether K wires are necessarily advantageous over plaster casting alone(41). Optimal wire configuration is unproven, although conventionally two to three 1.1 to 1.6mm K wires are adequate, with intra-focal wiring a useful technique to aid reduction(42). Post-operatively, patients are commonly placed in a plaster cast, with subsequent wire removal recommended at around four weeks. ORIF with VLP (utilising a modified Henry's or flexi-carpi radialis, FCR, approach) has become an increasingly popular option, with literature implying stronger fixation, improved radiological outcomes, subsequent earlier return to normal activities, and better functional outcomes, thereby justifying the higher cost of the implant. (43, 44) (45) (46)(47)(48)(49). In unstable fracture patterns, a recent meta-analysis demonstrated functional outcomes (supination and grip strength) to be better with VLP than K wire fixation (50). However, ORIF is not without complications; while the literature quotes rates ranging from4.9 to 80 percent due to variability in reporting and heterogeneity in the definition of 'complication', results from the larger cohorts suggest complication rates of up to 32 per cent. (51)Complications include neurovascular problems (injury up to 3.7 per cent, carpal tunnel syndrome up to 14 per cent), tendon complications including tenosynovitis/rupture (up to 12 per cent), metalwork problems (up to 10.5 per cent), complex regional pain syndrome (CRPS, up to 9 per cent),infection (up to 4 per cent), wound problems including sensitivity (up to 4 per cent), and malunion (up to 2 per cent)(37)(52)(53)(54). Quoted rates for redisplacement (average 1.5 per cent) and reoperation (average 1.9 per cent) are more heterogeneous between reported studies. Techniques to improve fixation include initially utilising a distal row of screws parallel to the joint surface, subsequent use of an initial proximal non-locking screw to ensure the plate then sits flush with the bone, alongside ensuring screws are not too long (i.e. do not enter the distal radio-ulnar or radio-carpal joint) or irritate tendons(42). However, influenced in no small part by the findings of the pragmatic DRAFFT study, among others, UK NICE guidance now advocates K wire fixation and casting provided there is a) "no fracture of the articular surface of the radial carpal joint" (i.e. an extra-articular fractures), or b) "displacement of the radial carpal joint can be reduced by closed manipulation", with a body of evidence suggesting no significant differences in functional outcome in the medium-term between K wire and VLP fixation, alongside lower overall healthcare costs (8) (45) (55)(56)(57). Furthermore, there is also some evidence to suggest no significant radiographic differences in reduction between K wire and ORIF of intraarticular fractures (6) (58). DRAFFT, a pragmatic, multicentre, randomised controlled trial of 461 adults with dorsally displaced DRFs, compared K wire fixation with VLPs, in fractures that could be reduced closed. Those requiring open reduction, for example significantly displaced intraarticular fractures, were excluded. The findings, that there were no significant differences in functional outcome (based on patient reported outcome measures) or complications between K wire and VLP fixation at 12 months, have changed practice in the UK, with a fall in the use of VLP (75 per cent of all fixation to 48 per cent) and a corresponding rise in K wire usage, (12 per cent to 42 per cent), four years following this publication(59). Techniques such as arthroscopically-assisted fixation are uncommonly used, although the evidence base reiterates the importance of anatomical reduction and minimising any intraarticular step (ideally to less than one mm) to minimise the risk of future arthritis(60). Ultimately, the goal remains anatomical reduction, with persistent articular incongruence after healing proposed to lead to earlier degenerative changes and poorer outcomes(61). While associated ulnar styloid fractures correlate with poorer outcomes (possibly due to DRUJ injury or TFCC related instability), the evidence-base does not conclude any benefit to surgical fixation of concomitant ulnar styloid fractures provided the distal radio-ulnar joint (DRUJ) is stable during examination under anaesthetic (i.e. no significant displacement when balloted, and no significant block to supination)(62)(63). An unstable DRUJ following untreated TFCC injury can result in poorer grip strength and ulnar sided wrist pain; in rare cases where there is felt to be persistent intra-operative instability of the DRUJ, options include arthroscopic evaluation and ligament repair, immobilisation of the joint in a position of stability, fixation of the ulnar styloid fracture, or the use of K wires to help maintain reduction(64)(65). In more complex scenarios (e.g. polytrauma, significant soft tissue injury, marked comminution and instability), either spanning or non-joint spanning internal or external fixation can play a role, helping to maintain overall fragment alignment, and allowing soft tissues to settle. However, external fixation cannot easily correct loss of volar tilt, and is not without complications such as pin-site infections. Indeed, for the majority of adults with more straightforward, closed, dorsally displaced DRFs, there is evidence that ORIF yields superior functional outcomes and fewer complications to external fixation at upto one year follow-up (66)(67)(68)(69)(70).

Rehabilitation and outcomes

Immobilisation should permit a full closed fist to be performed (i.e. should not extend beyond the metacarpophalangeal joints), so active finger and elbow motion should be maintained for light activities such as self-care immediately following injury (6). Active rehabilitation should promptly commence on removal of immobilisation. While the evidence base to guide specific rehabilitation protocols is limited, patients should be offered advice on exercises to self-maintain and improve all upper limb joint motion (i.e. gentle usage of wrist and hand to maintain independence, avoiding forced grasp) to overcome any stiffness secondary to immobilisation and swelling. Those that experience difficulty (e.g. ongoing stiffness, disproportionate pain or swelling, delayed return to function, concerns regarding development of chronic regional pain syndrome) should have early onward referral to physiotherapy(71). Earlier range of motion and strengthening may yield earlier return to clinically relevant function, although the evidence base does not suggest that active therapist-led programmes are significantly superior to self-directed programmes in the longer term(72)(73). Chronic regional pain syndrome (CRPS) is a serious complication following DRF, with some cohorts reporting rates as high as 39 per cent(74). Features include disproportionate pain, skin changes (e.g. erythema), and soft tissue swelling. While early mobilisation and hand therapy is likely to be of benefit, there is no evidence to support the routine use of vitamin C in preventing CRPS following DRF (75). The goals of treatment are to reduce pain and swelling, and to improve function. There is no consensus on the best patient reported outcome measure (PROM) to evaluate outcomes of DRFs, although the Patient Rated Wrist Evaluation (PRWE) and Disability of the Arm Shoulder and Hand Outcome Measure (DASH) scores are commonly used, with the evidence base suggesting 'moderate' positive responsiveness (76)(77) (78). Prognostic factors associated with poorer outcomes (primarily greater pain and disability in all age groups, alongside subsequent fragility fracture and functional decline in older adults), include older age, concomitant ulnar styloid fracture, female sex, litigation and occupational compensation, poorer bone health, and lower socioeconomic status; healthcare professionals should be cognizant of these groups of patients, with earlier consideration of referral for physiotherapy and secondary prevention measures(2).

Fragility fractures: risk assessment and prevention of future fractures

Fragility fractures occur secondary to low energy trauma (e.g. fall from standing height) in patients with impaired bone quality. They occur in one-third of men and one-half of women aged over 50 years(6).With DRF being the commonest fractures in post-menopausal women, a significant proportion of DRFs warrant investigation of any underlying bone health abnormality and falls risk(79). DRFs may be 'herald' fractures and predictors of future fragility fracture in certain groups, such as post-menopausal women(80). For example, there is growing evidence to suggest that women who suffer a DRF have a higher risk of subsequent hip fracture(81). These patients therefore represent an important cohort for targeted interventions to prevent further fracture. NICE CG 146 Osteoporosis guidelines recommend risk factor assessment in men aged 75 years and over, and women aged 65 years and over (or younger if other risk factors are present, including previous fragility fracture, current or frequent recent systemic glucocorticoid usage, falls history, family history of hip fracture, low Body Mass Index (below 18.5kg/m2), smoking, alcohol intake over 14 units/week (women) or 21 units/week (men), other secondary causes of osteoporosis)(82)(83). Risk assessment can utilise scoring systems (e.g. FRAX, QFracture), or duel-energy absorptiometry (DEXA) scanning of Bone Mineral Density (BMD). Patients aged under 50 years may rarely require assessment if the major risk factors discussed are present. The NICE Falls guidance CG161 assessment recommends screening through asking patients whether they have fallen in the past year; if they have, then the frequency/context/characteristics of the fall(s) must be ascertained(84). Those with risk factors should be referred to a local (physician-led) falls assessment service. While most patients with DRF are unlikely to encounter a general/elderly-care physician during their day case perioperative course, establishing an appropriate fracture liaison service (administered as an adjunct to the routine orthopaedic outpatient fracture clinic)is advocated as part of the UK's Falls and Fragility Fracture Audit programme (FFFAP) and Fracture Liaison Service Database (FLS-DB)(85)(86). The UK BOA BOAST 7 guidelines on Fracture Clinic Services further reinforce the recommendation to fully integrate such services into fracture clinics, with 'screening of all patients and onward referral where appropriate'(87). A final consideration is the importance of appropriately counseling patients on the longer term sequelae of their injuries. Several studies have demonstrated a failure to reduce intra-articular steps can lead to longer-term radiographic osteoarthritic changes due to even small (1mm) steps causing significant increase in contact stresses(88)(89).While the majority of these patients are symptomatic to some degree in later years, the correlation between joint incongruity, severity of arthritic symptoms, and function is unclear, with one study reporting the majority (87 per cent) of patients to report no difference between injured and uninjured wrists at 30 years follow up(90). Patients should therefore be advised regarding the potential for future problems (as DRFs can result in injury to the cartilage), and provided guidance on how to seek appropriate follow up.

Paediatric DRFs

DRFs are the commonest fractures in children, comprising up to 84 per cent of all paediatric forearm fractures(91). With significant remodelling potential, particularly in younger children, the majority can be managed non-operatively with immobilisation for three to six weeks, with or without manipulation, and with few long-term complications.(92). Fewer than 15 per cent require manipulation(93)(94). With a thick periosteal sleeve, softer bone, and open physis, unique fracture types are encountered in children, including simple buckle/torus fractures, greenstick fractures, and physeal injuries (Salter-Harris fractures), alongside adult-type extraarticular complete DRFs.(Figure 5)

Buckle/torus fractures

These are very common injuries in children and account for around half a million emergency department visits each year in the UK(8). The majority are dorsal compression buckle fractures of the distal radius, with no volar cortical breach (i.e. greenstick fractures), no concomitant ulnar fracture, and less than 15 degrees of angulation; they are therefore stable injuries, with low risk of displacement due to an intact periosteal sleeve(95). However, management varies in practice, ranging from simple analgesia and no immobilisation, to the use of bandages, removable splints, soft/removable casts, or rigid short-arm plaster casts. Management should consider the age and activity levels of the child, although there is limited evidence to suggest that removable soft splinting is preferable in terms of functional outcome, convenience and satisfaction, with no significant increase in overall levels of pain(96, 97). Rigid casts are not required. In general, the splint should be used day and night, generally for a period of three weeks, to help restrict activity and aid healing. Parents should be provided with subsequent removal-at-home instructions and 'red flag' advice, with a contact number for a plaster room service. Formal fracture clinic follow up is not needed unless there are specific concerns; buckle fractures are therefore ideally suited to management through virtual or remote fracture clinic services, resulting in improved service efficiency through fewer outpatient visits(98)(99)(100).

Greenstick and extra-articular complete DRFs

Greenstick fractures are potentially unstable and should not be confused with stable buckle fractures(101). These can re-displace after two weeks and therefore warrant both, three-point moulded full plaster casting (paying due attention to cast index), alongside close follow up to ensure no unacceptable increase in angulation(94)(102). Consensus also remains divided on whether plasters should be above or below elbow, but a below elbow plaster cast is recommended in UK national guidance(8). Re-displacement rates ranging from 29 to 91 per cent have been reported following initial closed reduction and casting of displaced paediatric DRFs (103) (104) (105) (106). While the evidence base is sparse, fractures with significant translation or complete displacement (i.e. off-ended fractures) or those that cannot be 'acceptably' reduced closed are more likely to re-displace and may therefore warrant II-guided manipulation under anaesthesia, with K wire stabilisation (generally two wires stabilising the fracture across two planes)(107)(108). Nonetheless, in the immature skeleton, a greater degree of angulation is tolerated, with significant remodelling potential, particularly in children more than two years away from skeletal maturity (109). The younger the child (i.e. greater number of years until skeletal maturity) and the closer to the physis the fracture, the greater the remodelling potential. While the evidence and consensus significantly varies, it is often accepted that, with metaphyseal fractures and their inherently greater remodelling potential, up to 20 degrees of dorsal angulation is well tolerated in children aged less than 10 years, and up to 10 degrees in those aged 10 years or over. Some authors propose accepting even greater degrees of dorsal angulation without future problems, with figures of up to 30 degrees in under 10 year olds and 20 degrees in over 10 year olds cited by some studies. Particularly in children aged under 10 years, complete displacement (bayonet apposition – i.e. overlap of up to 1 cm) may be well-tolerated, alongside 30 to 45 degrees of malrotation, provided more than two years to skeletal maturity remain, with no long-term restriction, pain or stiffness. Rotational deformities generally do not remodel as well, so should be corrected(91)(110) (107) (108) (111). For children within two years of skeletal maturity, anatomical reduction parameters (as for adults) should be accepted.

Paediatric physeal fractures

Approximately 15 per cent of paediatric DRFs involve the distal radial physis; these most commonly occur in children aged between 10 to 16 years (112). Salter-Harris type II fractures are the commonest (up to 80 per cent), and have high remodelling potential in all age groups, particularly those under ten years of age(113). These rarely result in growth disturbance, although the literature quotes growth problems in up to seven per cent of cases(114). As with all paediatric DRFs, remodelling potential diminishes with increasing age, with those aged 10 years and under rarely failing to completely remodel, and those aged over 10 years are more likely to experience incomplete remodelling (5). Accepted deformities and remodelling rates with physeal injuries are felt to be similar to other paediatric DRFs. If required, any manipulation should be gentle, with ideally a maximum of one attempt to avoid iatrogenic injury to the physis. Those presenting more than 10 days following the injury should not undergo manipulation due to an increased risk of physeal arrest(115).

Discussion

DRFs are one of the commonest injuries, with a bimodal distribution. Reducing cost of care and improving the speed of rehabilitation is relevant as epidemiological studies predict a rise in the global number of DRFs, secondary to a growing and ageing population, resulting in rising costs for healthcare systems and society(116). Pain and disability are the two main concerns among patients following distal radius fractures(2). Patients typically regain their function approximately one year after DRF, although rest or activity pain can persist in some for up to two years (117). Litigation and occupational compensation claims are reported as important predictors of pain, disability, and duration of lost function among patients with upper limb fractures, including DRF(118). Minimising immobilisation and aiming for early functional rehabilitation is therefore of importance. Acute management, ongoing follow-up, and subsequent rehabilitation must consider individual patient factors, including mechanism of injury, age, gender, functional status and demand, medical comorbidities (including falls risk and bone heath), alongside the fracture pattern. The evidence base on the management of DRFs is generally limited, with significant heterogeneity, and few high quality studies. Most national guidelines therefore incorporate expert consensus. The evidence base challenges common practices such as prolonged immobilisation (with a focus on earlier active patient-led rehabilitation) alongside the rising use of VLPs. In addition, DRFs are often deemed predictive of future fragility fractures, as part of a 'fracture cascade', with cohort data demonstrating association with an increased risk of vertebral fractures (five-fold for women, 10-fold for men), and a two-fold increase in hip fractures in women aged over 70 years(119)(120). Their management must therefore include proactive assessment and management of bone health and falls risk (3). Numerous unanswered questions remain. There is a need to agree the optimal objective (radiological parameters) and subjective (patient reported outcomes) measures for DRFs to guide evaluation of the various treatment modalities. Further research is also needed to more precisely guide appropriate selection between the common treatment modalities, including functional splinting and early mobilisation, plaster casting, K wire fixation, and VLPs. Following the high profile DRAFFT study, a fall in VLP usage has been observed in the UK (59). A follow up randomised controlled trial (RCT) is ongoing to evaluate the differences in outcome between K wiring and plaster cast alone (41). As DRFs pose a growing burden, a better understanding of these issues can help improve outcomes and drive down costs in patients with these common yet disabling injuries.

Conclusions:

DRFs are common orthopaedic injuries. There is some good quality evidence to help guide treatment. There remains ambiguity as to acceptable radiological parameters, the optimal treatment option for different fracture patterns, and the relationship between malunion and outcome. High-quality research is therefore needed to investigate these various aspects. (Table 2)

References

1. O'Neill TW, Cooper C, Finn JD, Lunt M, Purdie D, Reid DM, et al. Incidence of distal forearm fracture in British men and women. Osteoporosis International. 2001;12(7):555-8.
2. MacIntyre NJ, Dewan N. Epidemiology of distal radius fractures and factors predicting risk and prognosis. J Hand Ther. 2016;29(2):136-45.
3. Stirling ERB, Johnson NA, Dias JJ. Epidemiology of distal radius fractures in a geographically defined adult population. J Hand Surg Eur Vol. 2018;43(9):974-82.
4. Handoll HH, Madhok R. From evidence to best practice in the management of fractures of the distal radius in adults: working towards a research agenda. BMC Musculoskelet Disord. 2003;4(1):27.
5. Houshian S, Holst AK, Larsen MS, Torfing T. Remodeling of Salter-Harris type II epiphyseal plate injury of the distal radius. J Pediatr Orthop. 2004;24(5):472-6.
6. BOA (British Orthopaedic Association) and BSSH (British Society for Surgery of the Hand). Best practice for management of Distal Radial Fractures (DRFs). 2018.
7. NICE (National Institute for Health and Care Excellence). NICE Guideline (NG38): Fractures (complex): assessment and management 2016 [updated 17/2/2016. Available from: http://nice.org.uk/guidance/ng37.
8. NICE (National Institute for Health and Care Excellence). NICE Guideline (NG38): Fractures (non-complex): assessment and management 2016 [updated 17/12/2016. Available from: http://nice.org.uk/guidance/ng38.
9. AAOS (American Academy of Orthopaedic Surgeons). The treatment of distal radius fractures. Guideline and evidence report. 2009 5/12/2009.
10. Danish Health Authority. National clinical guideline on the treatment of distal radial fractures Copenhagen, Denmark; 2016.
11. Ilyas AM. Surgical approaches to the distal radius. Hand (N Y). 2011;6(1):8-17.
12. Maheshwari J. Injuries of the forearm and wrist. Essential Orthopaedics: Jaypee Brothers Medical Publishers Ltd, New Delhi: India; 2011. p. 108-16.
13. BOA (British Orthopaedic Association) and BSSH (British Society for Surgery of the Hand). British Orthopaedic Association Audit Standards for Trauma (BOAST): The Management of Distal Radius Fractures. 2017.
14. BOA (British Orthopaedic Association) and BAPRAS (British Association of Plastic RaAS. British Orthopaedic Association Audit Standards for Trauma (BOAST): Open Fractures. 2017.
15. Rikli DC, D. Surgical anatomy of the distal radius. In: Buckley RM, C; Apivatthakakul, T, editor. AO Principles of Fracture Management. Third ed: AO Foundation Publishing; 2017.
16. Shehovych A, Salar O, Meyer C, Ford DJ. Adult distal radius fractures classification systems: essential clinical knowledge or abstract memory testing? Ann R Coll Surg Engl. 2016;98(8):525-31.
17. Andersen DJ, Blair WF, Steyers CM, Jr., Adams BD, el-Khouri GY, Brandser EA. Classification of distal radius fractures: an analysis of interobserver reliability and intraobserver reproducibility. J Hand Surg Am. 1996;21(4):574-82.
18. Knirk JL, Jupiter JB. Intra-articular fractures of the distal end of the radius in young adults. J Bone Joint Surg Am. 1986;68(5):647-59.
19. Kelly AJ WD, Crichlow TP, Bannister GC. Is manipulation of moderately displaced Colles' fracture worthwhile? A prospective randomized trial. Injury. 1997;28:283-7.
20. Cobb AG, Houghton GR. Local anaesthetic infiltration versus Bier's block for Colles' fractures. Br Med J (Clin Res Ed). 1985;291(6510):1683-4.
21. Abbaszadegan H, Jonsson U. Regional anesthesia preferable for Colles' fracture. Controlled comparison with local anesthesia. Acta Orthop Scand. 1990;61(4):348-9.
22. Wardrope J, Flowers M, Wilson DH. Comparison of local anaesthetic techniques in the reduction of Colles' fracture. Arch Emerg Med. 1985;2(2):67-72.
23. Kendall JM AP, Younge P, Meek SM, McCabe SE. Haematoma block or Bier's block for Colles' fracture reduction in the accident and emergency department--which is best? Emergency Medicine Journal. 1997;14(6):352-6.
24. McCarty EC, Mencio GA, Walker LA, Green NE. Ketamine sedation for the reduction of children's fractures in the emergency department. J Bone Joint Surg Am. 2000;82-A(7):912-8.
25. Fernandez DL. Closed manipulation and casting of distal radius fractures. Hand Clin. 2005;21(3):307-16.
26. Slutsky DJ, Osterman AL. Fractures and injuries of the distal radius and carpus: the cutting edge: Elsevier Health Sciences; 2009.
27. Charnley J. The closed treatment of common fractures: Cambridge university press; 2005.
28. Gelberman RH, Szabo RM, Mortensen WW. Carpal tunnel pressures and wrist position in patients with colles' fractures. J Trauma. 1984;24(8):747-9.
29. Iltar S, Alemdaroglu KB, Say F, Aydogan NH. The value of the three-point index in predicting redisplacement of diaphyseal fractures of the forearm in children. Bone Joint J. 2013;95-B(4):563-7.
30. Tang J-B, Shi D, Gu YQ, Zhang QG. Can cast immobilization successfully treat scapholunate dissociation associated with distal radius fractures? Journal of Hand Surgery. 1996;21(4):583-90.
31. Dias JJ, Wray CC, Jones JM, Gregg PJ. The value of early mobilisation in the treatment of Colles' fractures. J Bone Joint Surg Br. 1987;69(3):463-7.
32. O'connor D MH, Doyle M, Mofidi A, Kutty S, O'SULLIVAN M. Minimally displaced Colles' fractures: a prospective randomized trial of treatment with a wrist splint or a plaster cast. Journal of Hand Surgery. 2003;28(1):50-3.
33. Walenkamp MM, Vos LM, Strackee SD, Goslings JC, Schep NW. The Unstable Distal Radius Fracture—How Do We Define It? A Systematic Review. Journal of wrist surgery. 2015;4(4):307.
34. Lafontaine M, Hardy D, Delince P. Stability assessment of distal radius fractures. Injury. 1989;20(4):208-10.
35. Mackenney PJ, McQueen MM, Elton R. Prediction of instability in distal radial fractures. J Bone Joint Surg Am. 2006;88(9):1944-51.
36. Arora R, Lutz M, Deml C, Krappinger D, Haug L, Gabl M. A prospective randomized trial comparing nonoperative treatment with volar locking plate fixation for displaced and unstable distal radial fractures in patients sixty-five years of age and older. J Bone Joint Surg Am. 2011;93(23):2146-53.
37. Arora R, Lutz M, Hennerbichler A, Krappinger D, Espen D, Gabl M. Complications following internal fixation of unstable distal radius fracture with a palmar locking-plate. J Orthop Trauma. 2007;21(5):316-22.
38. Aktekin CN, Altay M, Gursoy Z, Aktekin LA, Ozturk AM, Tabak AY. Comparison between external fixation and cast treatment in the management of distal radius fractures in patients aged 65 years and older. J Hand Surg Am. 2010;35(5):736-42.
39. Egol KA, Walsh M, Romo-Cardoso S, Dorsky S, Paksima N. Distal radial fractures in the elderly: operative compared with nonoperative treatment. J Bone Joint Surg Am. 2010;92(9):1851-7.
40. Bartl C, Stengel D, Gulke J, Gebhard F. [Clinical results following conservative and surgical treatment of osteoporotic distal radius fractures in the elderly : Overview of best available evidence]. Der Unfallchirurg. 2016;119(9):723-31.
41. NDORMS (Nuffield Department of Orthopaedics Rheumatology and Musculoskeletal Sciences). DRAFFT 2: Distal Radius Acute Fracture Fixation Trial 2 [Available from: https://www.ndorms.ox.ac.uk/clinical-trials/current-trials-and-studies/drafft-2.
42. Giddins GL, I. Avoiding Litigation in the Treatment of Wrist Fractures. Journal of Trauma and Orthopaedics. 2014;2(3):41 - 2.
43. Karantana A, Downing ND, Forward DP, Hatton M, Taylor AM, Scammell BE, et al. Surgical treatment of distal radial fractures with a volar locking plate versus conventional percutaneous methods: a randomized

controlled trial. J Bone Joint Surg Am. 2013;95(19):1737-44.

44. Downing ND, Karantana A. A revolution in the management of fractures of the distal radius? J Bone Joint Surg Br. 2008;90(10):1271-5.

45. Rozental TD, Blazar PE, Franko OI, Chacko AT, Earp BE, Day CS. Functional outcomes for unstable distal radial fractures treated with open reduction and internal fixation or closed reduction and percutaneous fixation. A prospective randomized trial. J Bone Joint Surg Am. 2009;91(8):1837-46.

46. Marcheix PS, Dotzis A, Benko PE, Siegler J, Arnaud JP, Charissoux JL. Extension fractures of the distal radius in patients older than 50: a prospective randomized study comparing fixation using mixed pins or a palmar fixed-angle plate. J Hand Surg Eur Vol. 2010;35(8):646-51.

47. McFadyen I, Field J, McCann P, Ward J, Nicol S, Curwen C. Should unstable extra-articular distal radial fractures be treated with fixed-angle volar-locked plates or percutaneous Kirschner wires? A prospective randomised controlled trial. Injury. 2011;42(2):162-6.

48. Hollevoet N, Vanhoutie T, Vanhove W, Verdonk R. Percutaneous K-wire fixation versus palmar plating with locking screws for Colles' fractures. Acta Orthop Belg. 2011;77(2):180-7.

49. Gouk CJC, Bindra RR, Tarrant DJ, Thomas MJE. Volar locking plate fixation versus external fixation of distal radius fractures: a meta-analysis. J Hand Surg Eur Vol. 2018;43(9):954-60.

50. Peng F, Liu YX, Wan ZY. Percutaneous pinning versus volar locking plate internal fixation for unstable distal radius fractures: a meta-analysis. J Hand Surg Eur Vol. 2018;43(2):158-67.

51. McKay SD, MacDermid JC, Roth JH, Richards RS. Assessment of complications of distal radius fractures and development of a complication checklist. J Hand Surg Am. 2001;26(5):916-22.

52. Diaz-Garcia RJ, Oda T, Shauver MJ, Chung KC. A systematic review of outcomes and complications of treating unstable distal radius fractures in the elderly. J Hand Surg Am. 2011;36(5):824-35 e2.

53. Johnson NA, Cutler L, Dias JJ, Ullah AS, Wildin CJ, Bhowal B. Complications after volar locking plate fixation of distal radius fractures. Injury. 2014;45(3):528-33.

54. Yuan ZZ YZ, Liu Q, Liu YM. Complications following open reduction and internal fixation versus external fixation in treating unstable distal radius fractures: Grading the evidence through a meta-analysis. Orthopaedics & Traumatology: Surgery & Research. 2018;104(1):95-103.

55. Costa ML, Achten J, Parsons NR, Rangan A, Griffin D, Tubeuf S, et al. Percutaneous fixation with Kirschner wires versus volar locking plate fixation in adults with dorsally displaced fracture of distal radius: randomised controlled trial. BMJ. 2014;349:g4807.

56. Goehre F, Otto W, Schwan S, Mendel T, Vergroesen PP, Lindemann-Sperfeld L. Comparison of palmar fixed-angle plate fixation with K-wire fixation of distal radius fractures (AO A2, A3, C1) in elderly patients. J Hand Surg Eur Vol. 2014;39(3):249-57.

57. Chaudhry H, Kleinlugtenbelt YV, Mundi R, Ristevski B, Goslings JC, Bhandari M. Are Volar Locking Plates Superior to Percutaneous K-wires for Distal Radius Fractures? A Meta-analysis. Clinical orthopaedics and related research. 2015;473(9):3017-27.

58. Johnson NA, Dias JJ, Wildin CJ, Cutler L, Bhowal B, Ullah AS. Comparison of distal radius fracture intra-articular step reduction with volar locking plates and K wires: a retrospective review of quality and maintenance of fracture reduction. J Hand Surg Eur Vol. 2017;42(2):144-50.

59. Costa M, Jameson S, Reed M. Do large pragmatic randomised trials change clinical practice? Assessing the impact of the distal radius acute fracture fixation trial (DRAFFT). The bone & joint journal. 2016;98(3):410-3.

60. Mehta JA, Bain GI, Heptinstall RJ. Anatomical reduction of intra-articular fractures of the distal radius. An arthroscopically-assisted approach. J Bone Joint Surg Br. 2000;82(1):79-86.

61. Leung F, Tu YK, Chew WY, Chow SP. Comparison of external and percutaneous pin fixation with plate fixation for intra-articular distal radial fractures. A randomized study. J Bone Joint Surg Am. 2008;90(1):16-22.

62. Souer JS, Ring D, Matschke S, Audige L, Marent-Huber M, Jupiter JB, et al. Effect of an unrepaired fracture of the ulnar styloid base on outcome after plate-and-screw fixation of a distal radial fracture. J Bone Joint Surg Am. 2009;91(4):830-8.

63. Kim JK, Koh YD, Do NH. Should an ulnar styloid fracture be fixed following volar plate fixation of a distal radial fracture? J Bone Joint Surg Am. 2010;92(1):1-6.

64. Harvey J, editor Treatment of concomitant injuries of the DRUJ. BMC proceedings; 2015: Springer.

65. Gong HS, Cho HE, Kim J, Kim MB, Lee YH, Baek GH. Surgical treatment of acute distal radioulnar joint instability associated with distal radius fractures. J Hand Surg Eur Vol. 2015;40(8):783-9.

66. Landgren M, Jerrhag D, Tagil M, Kopylov P, Geijer M, Abramo A. External or internal fixation in the treatment of non-reducible distal radial fractures? Acta Orthop. 2011;82(5):610-3.

67. Cui Z, Pan J, Yu B, Zhang K, Xiong X. Internal versus external fixation for unstable distal radius fractures: an up-to-date meta-analysis. Int Orthop. 2011;35(9):1333-41.

68. Richard MJ, Wartinbee DA, Riboh J, Miller M, Leversedge FJ, Ruch DS. Analysis of the complications of palmar plating versus external fixation for fractures of the distal radius. J Hand Surg Am. 2011;36(10):1614-20.

69. Esposito J, Schemitsch EH, Saccone M, Sternheim A, Kuzyk PR. External fixation versus open reduction with plate fixation for distal radius fractures: a meta-analysis of randomised controlled trials. Injury. 2013;44(4):409-16.

70. Xie X, Xie X, Qin H, Shen L, Zhang C. Comparison of internal and external fixation of distal radius fractures. Acta Orthop. 2013;84(3):286-91.

71. Handoll HH, Elliott J. Rehabilitation for distal radial fractures in adults. The Cochrane database of systematic reviews. 2015(9):CD003324.

72. Magnus CR, Arnold CM, Johnston G, Dal-Bello Haas V, Basran J, Krentz JR, et al. Cross-education for improving strength and mobility after distal radius fractures: a randomized controlled trial. Archives of physical medicine and rehabilitation. 2013;94(7):1247-55.

73. Brehmer JL, Husband JB. Accelerated rehabilitation compared with a standard protocol after distal radial fractures treated with volar open reduction and internal fixation: a prospective, randomized, controlled study. J Bone Joint Surg Am. 2014;96(19):1621-30.

74. Li Z, Smith BP, Tuohy C, Smith TL, Andrew Koman L. Complex regional pain syndrome after hand surgery. Hand Clin. 2010;26(2):281-9.

75. Evaniew N, McCarthy C, Kleinlugtenbelt YV, Ghert M, Bhandari M. Vitamin C to Prevent Complex Regional Pain Syndrome in Patients With Distal Radius Fractures: A Meta-Analysis of Randomized Controlled Trials. J Orthop Trauma. 2015;29(8):e235-41.

76. Hudak PL, Amadio PC, Bombardier C. Development of an upper extremity outcome measure: the DASH (disabilities of the arm, shoulder and hand) [corrected]. The Upper Extremity Collaborative Group (UECG). American journal of industrial medicine. 1996;29(6):602-8.

77. Macey AC, Burke FD, Abbott K, Barton NJ, Bradbury E, Bradley A, et al. Outcomes of hand surgery. British Society for Surgery of the Hand. J Hand Surg Br. 1995;20(6):841-55.

78. Schonnemann JO, Larsen K, Hansen TB, Soballe K. Reliability and validity of the Danish version of the disabilities of arm, shoulder, and hand questionnaire in patients with fractured wrists. Journal of plastic surgery and hand surgery. 2011;45(1):35-9.

79. Crandall CJ, Hovey KM, Cauley JA, Andrews CA, Curtis JR, Wactawski-Wende J, et al. Wrist Fracture and Risk of Subsequent Fracture: Findings from the Women's Health Initiative Study. J Bone Miner Res. 2015;30(11):2086-95.

80. Johnson NA, Stirling ER, Divall P, Thompson JR, Ullah AS, Dias JJ. Risk of hip fracture following a wrist fracture-A meta-analysis. Injury. 2017;48(2):399-405.

81. Johnson NA, Stirling E, Divall P, Thompson J, Ullah A, Dias J. Risk of hip fracture following a wrist fracture—A meta-analysis. Injury. 2017;48(2):399-405.

82. NICE (National Institute for Health and Care Excellence). Osteoporosis: fragility fracture risk. Osteoporosis: assessing the risk of fragility fracture. Short clinical guideline - CG146 Royal College of Physicians; 2012 [Available from: http://www.nice.org.uk/guidance/cg146/evidence/osteoporosis-fragility-fracture-full.

83. Harness NG, Funahashi T, Dell R, Adams AL, Burchette R, Chen X, et al. Distal radius fracture risk reduction with a comprehensive osteoporosis management program. J Hand Surg Am. 2012;37(8):1543-9.

84. NICE (National Instutute for Health and Care Excellence). Falls in older people: assessing risk and prevention. Clinical guideline [CG161] 2013 [Available from: https://www.nice.org.uk/guidance/cg161/chapter/1-recommendations#preventing-falls- in-older-people-2.

85. RCP (Royal College of Physicians). Falls and Fragility Fracture Audit Programme (FFFAP) 2013 [Available from: https://www.rcplondon.ac.uk/projects/falls-and-fragility-fracture-audit-programme-fffap

86. RCP (Royal College of Physicians). Fracture Liaison Service Database (FLS-DB) 2016 [Available from: https://www.rcplondon.ac.uk/projects/fracture-liaison-service-database-fls-db.

87. Association BO. British Orthopaedic Association Audit Standards for Trauma (BOAST): Fracture Clinic Services. 2013.

88. Wagner WF, Jr., Tencer AF, Kiser P, Trumble TE. Effects of intra-articular distal radius depression on wrist joint contact characteristics. J Hand

Surg Am. 1996;21(4):554-60.

89. Catalano LW, 3rd, Cole RJ, Gelberman RH, Evanoff BA, Gilula LA, Borrelli J, Jr. Displaced intra-articular fractures of the distal aspect of the radius. Long-term results in young adults after open reduction and internal fixation. J Bone Joint Surg Am. 1997;79(9):1290-302.

90. Kopylov P, Johnell O, Redlund-Johnell I, Bengner U. Fractures of the distal end of the radius in young adults: a 30-year follow-up. J Hand Surg Br. 1993;18(1):45-9.

91. Crawford SN, Lee LS, Izuka BH. Closed treatment of overriding distal radial fractures without reduction in children. J Bone Joint Surg Am. 2012;94(3):246-52.

92. Qairul IH, Kareem BA, Tan AB, Harwant S. Early remodeling in children's forearm fractures. Med J Malaysia. 2001;56 Suppl D:34-7.

93. Brudvik C, Hove LM. Childhood fractures in Bergen, Norway: identifying high-risk groups and activities. J Pediatr Orthop. 2003;23(5):629-34.

94. Randsborg PH, Sivertsen EA. Distal radius fractures in children: substantial difference in stability between buckle and greenstick fractures. Acta Orthop. 2009;80(5):585-9.

95. Solan MC, Rees R, Daly K. Current management of torus fractures of the distal radius. Injury. 2002;33(6):503-5.

96. Plint AC, Perry JJ, Correll R, Gaboury I, Lawton L. A randomized, controlled trial of removable splinting versus casting for wrist buckle fractures in children. Pediatrics. 2006;117(3):691-7.

97. Williams KG, Smith G, Luhmann SJ, Mao J, Gunn JD, 3rd, Luhmann JD. A randomized controlled trial of cast versus splint for distal radial buckle fracture: an evaluation of satisfaction, convenience, and preference. Pediatr Emerg Care. 2013;29(5):555-9.

98. Khan KS, Grufferty A, Gallagher O, Moore DP, Fogarty E, Dowling F. A randomized trial of 'soft cast' for distal radius buckle fractures in children. Acta Orthop Belg. 2007;73(5):594-7.

99. Beiri A, Alani A, Ibrahim T, Taylor GJ. Trauma rapid review process: efficient out-patient fracture management. Ann R Coll Surg Engl. 2006;88(4):408-11.

100. Symons S, Rowsell M, Bhowal B, Dias JJ. Hospital versus home management of children with buckle fractures of the distal radius. A prospective, randomised trial. J Bone Joint Surg Br. 2001;83(4):556-60.

101. Zamzam MM, Khoshhal KI. Displaced fracture of the distal radius in children: factors responsible for redisplacement after closed reduction. J Bone Joint Surg Br. 2005;87(6):841-3.

102. Mazzini JP, Martin JR. Paediatric forearm and distal radius fractures: risk factors and re-displacement—role of casting indices. International orthopaedics. 2010;34(3):407-12.

103. Voto SJ, Weiner DS, Leighley B. Redisplacement after closed reduction of forearm fractures in children. J Pediatr Orthop. 1990;10(1):79-84.

104. Gibbons CL, Woods DA, Pailthorpe C, Carr AJ, Worlock P. The management of isolated distal radius fractures in children. J Pediatr Orthop. 1994;14(2):207-10.

105. Proctor MT, Moore DJ, Paterson JM. Redisplacement after manipulation of distal radial fractures in children. J Bone Joint Surg Br. 1993;75(3):453-4.

106. Davis DR, Green DP. Forearm fractures in children: pitfalls and complications. Clinical orthopaedics and related research. 1976(120):172-83.

107. Fenton P, Nightingale P, Hodson J, Luscombe J. Factors in redisplacement of paediatric distal radius fractures. J Pediatr Orthop B. 2012;21(2):127-30.

108. Jordan RW, Westacott DJ. Displaced paediatric distal radius fractures--when should we use percutaneous wires? Injury. 2012;43(6):908-11.

109. Planka L, Chalupova P, Skvaril J, Poul J, Gal P. [Remodelling ability of the distal radius in fracture healing in childhood]. Rozhledy v chirurgii : mesicnik Ceskoslovenske chirurgicke spolecnosti. 2006;85(10):508-10.

110. Bae DS. Pediatric distal radius and forearm fractures. J Hand Surg Am. 2008;33(10):1911-23.

111. Noonan KJ, Price CT. Forearm and distal radius fractures in children. The Journal of the American Academy of Orthopaedic Surgeons. 1998;6(3):146-56.

112. Peterson CA, Peterson HA. Analysis of the incidence of injuries to the epiphyseal growth plate. J Trauma. 1972;12(4):275-81.

113. Lee BS, Esterhai JL, Jr., Das M. Fracture of the distal radial epiphysis. Characteristics and surgical treatment of premature, post-traumatic epiphyseal closure. Clinical orthopaedics and related research. 1984(185):90-6.

114. Cannata G, De Maio F, Mancini F, Ippolito E. Physeal fractures of the distal radius and ulna: long-term prognosis. J Orthop Trauma. 2003;17(3):172-9; discussion 9-80.

115. Dua K, Abzug JM, Sesko Bauer A, Cornwall R, Wyrick TO. Pediatric Distal Radius Fractures. Instructional course lectures. 2017;66:447-60.

116. Gauthier A, Kanis JA, Jiang Y, Martin M, Compston JE, Borgstrom F, et al. Epidemiological burden of postmenopausal osteoporosis in the UK from 2010 to 2021: estimations from a disease model. Archives of osteoporosis. 2011;6:179-88.

117. Ydreborg K, Engstrand C, Steinvall I, Larsson EL. Hand function, experienced pain, and disability after distal radius fracture. The American journal of occupational therapy : official publication of the American Occupational Therapy Association. 2015;69(1):6901290030.

118. MacDermid JC, Roth JH, McMurtry R. Predictors of time lost from work following a distal radius fracture. Journal of occupational rehabilitation. 2007;17(1):47-62.

119. Cuddihy MT, Gabriel SE, Crowson CS, O'Fallon WM, Melton LJ, 3rd. Forearm fractures as predictors of subsequent osteoporotic fractures. Osteoporosis international : a journal established as result of cooperation between the European Foundation for Osteoporosis and the National Osteoporosis Foundation of the USA. 1999;9(6):469-75.

120. Owen RA, Melton LJ, 3rd, Ilstrup DM, Johnson KA, Riggs BL. Colles' fracture and subsequent hip fracture risk. Clinical orthopaedics and related research. 1982(171):37-43.

Conflict of Interest: NIL
Source of Support: NIL

How to Cite this Article

Kulkarni K, Johnson N, Dias J. "Decision making in the management of distal radius fractures". Journal of Clinical Orthopaedics July-Dec 2018; 3(2):2-11