ORIGINAL ARTICLE

The challenge of the surgical treatment of paediatric distal radius/ forearm fracture: K wire vs plate fixation - outcomes assessment

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ABSTRACT

Aim Distal radius/forearm fractures in adolescent patients remain challenging injuries to treat. Distal radius/forearm bony anatomy is not completely restored with intramedullary K wire fixation. The aim of this study was to compare radiographic and functional outcomes obtained using intramedullary K wire fixation and open reduction and internal fixation in the treatment of distal radius/ forearm fracture.

Methods A total of 43 patients who presented with distal radius/ forearm fractures were enrolled and divided into two groups: 23 patients treated with K-wire (IMNK) and 20 patients treated with plate and screws (ORIF). The evaluation criteria were: fracture healing time, objective quality of life measured by the Mayo wrist score (MWS) and quick disabilities of the arm, shoulder and hand score (QuickDash), length time of surgery, complications, sport or play return, forearm visual analogic pain (FVAS), bone healing by radius union scoring system (RUSS).

Results In both groups the results obtained were comparable in terms of functional, pain and return to play/sport after the third month after surgery. Bone healing was faster in IMNK than ORIF but without significance ($p>0.05$). There was less complication in ORIF than IMNK ($p<0.05$).

Conclusion The treatment of adolescent distal radius or forearm fractures remains challenging. One challenge facing the physician is the choice of surgical technique and fixation method, which will be influenced by individual experience and preference.

The question of distal radius or forearm fractures in adolescents would be best answered with a prospective randomized study.

Key words: paediatric, pain, wrist

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Original submission:
13 November 2020;
Accepted:
17 November 2020
doi: 10.17392/1315-21

INTRODUCTION

Distal radius fractures are the most common fractures in children, amounting to around a quarter to a third of all paediatric fractures (1). Annual incidences of 30/10,000 children (aged 0 to 17 years) have been reported in the US during 2009 (2). The mean age of children (aged up to 16 years) presenting with these injuries in 2000 at two Edinburgh hospitals was 9.9 years and 55% were boys (3). The distribution of fractures is unimodal for both genders (3). In 2010, Hedström et al. reported peaks at 11 years for girls and 14 years for boys. Fractures are seen especially in pubertal growth ages (11–14 years in males, 8–11 years in females) and in spring and summer months when physical activity increases (3). Distal radius fractures most commonly result from a fall on an outstretched hand (3).

The rapid growth feature increases fracture tendency at the lower end of the radius, because distal metaphysis is relatively weak due to continuous remodelling. Displaced distal radius fractures are usually treated with closed reduction and intramedullary nail K wires (IMNK) (Figure 1) (4).

Prevention of the reduction loss is the main issue in conservative treatment (5). Distal radius/forearm fractures in adolescent patients remain challenging injuries to treat. Distal radius/forearm bony anatomy is not completely restored with IMNK. Results suggested an association towards increased complication rates and complication severity with intramedullary fixation (6). Nowadays open reduction and internal fixation with plates and screws (ORIF) are commonly used in the pubertal growth age (7) (Figure 2).

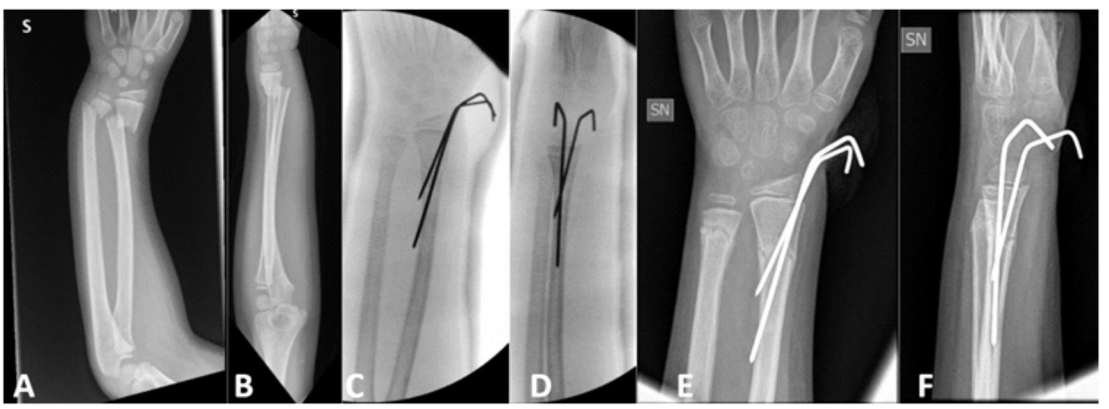

Figure 1. 12-year-old female with bike fall trauma to her left wrist. A, B) Preoperative X-rays showed the complete fracture of distal radius and ulna; C, D) post-surgery X-rays showed the intramedullary K wires fixation of only distal radius; E, F) the X-rays showed the bone healing after only one month from the surgery (Di Giacinto S, 2019)

Figure 2. 13-year-old male, sports trauma to the right wrist. A, B) Preoperative X-rays showed the complete fracture of distal radius and ulna; C, D) post-surgery X-rays showed the plate fixation on the radius and ulna; E, F) the X-rays showed the bone healing after only one month from the surgery (Di Giacinto S, 2019)

The aim of this study was to compare the radiographic and functional outcomes obtained using IMNK and ORIF in the treatment of distal radius/forearm fracture.

PATIENTS AND METHODS

Patients and study design

Among a total of 123 radius/forearm fractures of the patients admitted and treated at one Level I trauma Centre of Meyer University Children's Hospital, Florence and one Level II Trauma Centre of AORN San Pio, Benevento, from January 2017 to December 2019, 43 patients with distal/forearm fractures were finally included. Inclusion criteria were: patients admitted to our Centre for surgical treatment, patients fit for surgery, age between 12-14 years, bayonetting >1 cm, angulations >10°, malrotation >30°, dorsal angulation >20 degrees. Exclusion criteria were: haematological or oncological patients, acute or chronic infections, previous lower limb trauma, nerve injuries, segmental contralateral fracture, vessels injuries, age <12 and >14 years old, conservative treatment, fracture older than 21 days, distal physis, diaphysis, bayonetting <1 cm, angulations <10°, malrotation <30°, dorsal angulation <20 degrees, non 23-M/3 complete or 23r-M/3 complete type of fracture according to AO (*Arbeitsgemeinschaft für Osteosynthesefragen*) Classification (8), bone metabolism diseases, skeletal immaturity, mental or neurologic disorder.

All patients' parents were informed in a clear and comprehensive way of two types of treatments and other possible surgical and conservative alternatives. Patients were treated according to the Ethical Standards of the Helsinki Declaration, and were invited to read, understand, and sign an informed consent form.

Azienda Ospedaliera Mayer Firenze/Italy Ethical Committee approved this research.

Methods

All fractures were classified according to the AO Classification (8) Forty-three patients were divided in two groups: 20 patients treated with ORIF with plate and 23 patients treated with intramedullary K wire (IMNK) (Table 1).

Both groups underwent the same rehabilitation protocol (see rehabilitation protocol). To study the bone healing on radiographs, the Non-Union Scoring System (NUSS) was used (9). The criteria to evaluate the two groups during the follow-up were: the objective quality of life and the wrist function measured by the Mayo wrist score (MWS) (3), the subjective quality of life and the wrist function measured by quick disabilities of the arm, shoulder and hand score (QuickDASH) (3), length of surgery, complications, sport or play return, forearm visual analogue pain (VAS) (3), bone healing by radius union scoring system (RUSS (10). Union of each of the 4 cortices was graded on a 3-point scale: 0 - fracture line visible with no callus; 1 - callus formation but fracture line present, 2 - cortical bridging without clear fracture line. Reviewers also recorded their overall impression of fracture union (united or not united). Regarding radiographic measurements as volar tilt, radial inclination, radial length and others, standard posteroanterior, and lateral radiographs were used. The evaluation endpoint was set at 12 months after surgery.

Rehabilitation protocol. Casting historically consisted of a long arm cast for 6-8 weeks with the possibility of conversion to a short arm cast after 2-4 weeks depending on the type of fracture and healing response; may cast for shorter periods, 3-4 weeks, depending on child's age and healing on imaging; multiple high quality studies show fractures of distal third may be immobilized with a properly moulded short arm cast (4,6); special case of fractured distal radius with intact ulna: extreme ulna deviation of wrist helps keep radius fracture out to length.

During the cast period children may use the injured hand for light activities only and they should move their wrist and fingers within their pain tolerances straight away. It is advisable to take pain killers as prescribed to enable your child to complete the exercises.

Say to parents: *It is common for the wrist to ache and sometimes be painful for further 3-6 months after the injury*.

Stage 1 (after 4 weeks to 5 weeks after the surgery): finger and wrist flexion and extension, elbow bend and straighten, forearm rotations.

Another advice for the patient was: cold pack (ice pack or frozen peas wrapped in a damp towel) can provide short-term pain relief. *Apply this to the sore area for up to 15 minutes every few hours, ensuring the ice is never in direct contact with the skin*.

Stage 2 (after 5 weeks): 3-4 times a day, wrist flexion stretch, wrist extension stretch (prayer exercise), sideways wrist stretches.

Grip strength exercises. It is advisable to take pain killers as prescribed to enable your child to complete the exercises. Cold packs: can provide short-term pain relief. *Apply this to the sore area for up to 15 minutes every few hours, ensuring the ice is never in direct contact with the skin*.

Statistical analysis

Descriptive statistics were used to summarize the characteristics of the study group and subgroups, including mean and standard deviation of all continuous variables. The t-test was used to compare continuous outcomes. The $\chi 2$ test or Fisher's exact test (in subgroups smaller than 10 patients) were used to compare categorical variables. The statistical significance was defined as $p<0.05$. The Pearson correlation coefficient (r) was used to compare the predictive score of outcomes and quality of life. Mean age (and the range) of the patients was rounded at the closest year. The predictive score of outcome and quality of life and the range were approximated at the first decimal, while the Pearson correlation coefficient was approximated at the second decimal (r). Cohen's kappa coefficient (κ) was used to measure inter-rater agreement for qualitative (categorical) items; through this parameter we calculated the concordance between different qualitative values of the outcomes and the bone healing, the anatomical and biomechanical axis of the distal forearm from the radiological point of view.

RESULTS

There was no statistically significant difference between the two populations according to age, gender, type of fracture, NUSS, etc. (Table 1).

In 12 of 23 (52.17%) of IMNK group, it had to be open to reduce the fracture (Table 1).

The surgery lasted for an average of 32.6 (±11.6; range 15-42) minutes in IMNK ($p<0.05$), while

Figure 3. 13-year-old male with sports trauma to the right wrist. A, B) Preoperative X-rays showed the complete fracture of distal radius and ulna; C, D) post-surgery X-rays showed intramedullary K wires fixation on the radius and ulna; E, F) the X-rays showed non-union/malunion with dorsal angulation, bayoneting, and radial angulation of distal forearm. Healing after only one month from the remotion of IMNK; G, H) X-rays post re-surgery showed the anatomic reduction with plate and screws on radius and ulna, after the debridement and calloclasy of non-union focus; I, J) bilateral bone healing with exuberant callus on all cortices just one month after re-surgery (Meccariello L, 2019)

Table 1. Characteristics of the intramedullary K wire fixation (IMNK) and open reduction internal fixation (ORIF) patient's groups

Characteristic	IMNK (n=23)	ORIF (n=20)
Average age, years (standard deviation, SD)	12.86 (±0.64)	13.02 (±11.77)
Age range (years)	12-14	12-14
Gender ratio (No) (male:female)	1.875 (15:8)	1.857 (13:7)
Previous type of accident (No, %)		
Fall from height	8 (34.78)	5 (20)
Bike accident	4 (17.39)	5 (20)
Motorcycle accident	4 (17.39)	5 (20)
Sport accident	7 (30.44)	5 (20)
Previous type of femoral shaft fractures according to AO (8) (No, %)		
Non 23-M/3 complete	16 (69.56)	12 (60)
23r-M/3 complete	7 (30.44)	8 (40)
Type of fracture (No, %)		
Closed	23 (100)	23 (100)
Open	0	0
Injured upper limb side (No, %)		
Right	8 (34.78)	7 (35)
Left	15 (65.22)	13 (65)
Average non-union scoring system (SD)	4.89 (±1.33)	4.94 (±1.47)
Range non-union scoring system	0-15	0-15
Open to reduce the fracture (No, %)	12 (52.17)	20 (100%)

AO, Arbeitsgemeinschaft für Osteosynthesefragen

54.8 (±17.9; range 37-74) minutes for ORIF (Table 2).

The mean of follow-up was 16.86 (±5.64;12-36) months for IMNK and 16.37 (±5.77;12-36) months for ORIF (p>0.05) (Table 2).

In both groups, patients demonstrated appropriate wound healing within 21 days.

The average time of bone healing was 2.6 (±1.22;1-4) months after the surgery in IMNK, while it was 2.8 (±1.34;1-4) months for ORIF (p>0.05) (Table 2). The average time of bone healing in re-operated IMNK cases was 2.2 (±0.4; 1 -3) months.

At average day of the bone healing the RUSS was of 29.4 (±1.22;29-30) points in IMNK, while it was 29.8 (±0.1;29-30) in ORIF (p<0.05) (Table 2). At the last X-ray control before the breakage of the callus associated to malunion or non-union the RUSH was of 29.2 points in one case and 29.3 in the other case. At average day of the bone healing in the IMNK reoperated group, the RUSS was of 29.64 (±0.27; range 29.2-30).

In the average day of the bone healing the VAS was 0.8 (±0.2; range 0-1) point in IMNK, while it was 0.7 (±0.3; range 0-1) in ORIF (p>0.05) (Table 2). At the last follow up review before the breakage of the plates, the VAS was 1 point in one case and 2 in the other case. At average day of the bone healing in the ORIF re-operated group, the VAS was 2.3 (±0.57; range 2-3).

Table 2. The comparison of the patients treated with intramedullary nail K wire (IMNK) and open reduction and internal fixation with plate and screws (ORIF)

Variable	IMNK (n=23)	ORIF (n=20)	p
Average follow up, length of time of surgery (SD; range)	32.6 (±11.6; range 15-42)	54.8 (±17.9; range 37-74)	<0.05
Average follow up, month (SD; range)	16.86 (±5.64;12-36)	16.37 (±5.77;12-36)	>0.05
Average bone healing, month (SD; range)	2.6 (±1.22;1-4)	2.8 (±1.34;1-4)	>0.05
Average RUSS at the moment of bone healing, points (SD; range)	29.4 (±1.22;29-30)	29.8 (±0.1;29-30)	>0.05
Average VAS at the moment of bone healing, points (SD; range)	0.8 (±0.2; range 0-1)	0.7 (±0.3; range 0-1)	>0.05
Cohen's kappa (k) (SD; range)	0.89 (±0.11: 0.78-1)	0.91 (±0.09: 0.90-1)	<0.05
Pre-operative radiological characteristics of fracture			
Average bayonetting (SD; range) (cm)	1.56 (±0.32;1-3)	1.67 (±0.48;1-3)	>0.05
Average angulation (SD; range) (degrees)	36.4 (±8.77;29-52)	35.8 (±7.89;29-52)	>0.05
Average maltrotation (SD; range) (degrees)	33.7 (±2.55;30.1-36)	34.1 (±3.27;30.1-38)	>0.05
Average dorsal angulation (SD; range) (degrees)	24.6 (±2.55;20.1-27)	22.3 (±2.16;20.1-28)	>0.05
Post bone healing radiological characteristics of fracture			
Average Bayonetting, (SD; range) (cm)	0.47 (±0.23;0.3-0.8)	0.36 (±0.12;0.3-0.7)	>0.05
Average angulation (SD; range) (degrees)	4.23 (±1.37;0-8)	3.48 (±0.12;0-8)	>0.05
Average maltrotation (SD; range) (degrees)	2.64 (±1.41;0-6)	2.21 (±1.57;0-7)	>0.05
Average dorsal angulation (SD; range) (degrees)	15.64 (±3.82;0-20)	14.96 (±4.01;0-20)	>0.05
Complication (No, %)			
Skin Infection	3(13.04)	2 (10)	>0.05
Non-union	1 (4.34)	0*	<0.05
Malunion	1 (4.34)	0*	<0.05
Re-fractured	2 (8.69)	0*	<0.05
Daily outcomes (No, %)			
Return to sport	23 (100)	20 (100)	1.00

RUSS, radius union scoring system; VAS, Visual analogic pain; SD, Standard Deviation

At average day of bone healing the regression between RUSS and VAS scores showed a p=0.068 in IMNK, while p=0.043 in ORIF (p<0.05) for ORIF; at average day in IMNK re-operated group of bone healing, the regression between RUSS and VAS scores showed p=0.047.

The average correlation of clinical-radiographic results and patients' outcomes was high according Cohen κ: 0.89 (±0.11; range 0.78-1) for IMNK, while κ: 0.91 (±0.09; 0.90-1) for ORIF (p<0.05) (Table 2).

During the follow up no complications were noticed in ORIF group; instead, there were two non-union or malunion after the remotion of K wires ($p<0.05$) for ORIF (Table 2). The time of callus breakage or malunion with respect to surgery was: 47 days in one case and 61 days in the second case.

All the ORIF cases were re-operated using compression locking plate screws. All these surgeries were successfully performed and were uneventful.

There was no statistically significant difference in pre- and post-surgery X-rays between the two populations according to bayonetting, angulations, malrotation, dorsal angulation degrees (Table 2).

The objective quality of life and wrist function in IMNK's group before the trauma, measured by MWS, was about 100 points, while the quite quality of life before the trauma, measured by MWS, was about 100 points in ORIF ($p=1.00$). At the moment of trauma, in IMNK group the MWS was 14.3 (±2.4; range 0-26) in the same moment in ORIF group the MWS was 15.1 (±2.4; range 0-26) ($p>0.05$). After 1 month from the surgery the MWS score was 82.5 (±12.4; range 72-100) for IMNK and 92.4 (±5.4range 86-100) in ORIF ($p<0.05$) for ORIF. Also, the third month after the surgery ($p>0.05$), MWS score was 100 in IMNK and 100 in ORIF, as well as the sixth month of follow-up and at twelve months.

The subjective quality of life and wrist function of IMNK's group before the trauma, measured by QuickDASH, was about 100 points, while the quite quality of life before the trauma was about 100 points in ORIF ($p=1.00$). At the moment of trauma, in the IMNK group the QuickDASH was 15.3 (±3.7; range 0-26) and in the same moment ORIF, the QuickDASH was 15.6 (±3.6; range 0-26), $p>0.05$. After 1 month from the revision surgery the QuickDASH score was 80.4 (±9.2; range 70-100) in IMNK and 88.7 (±8.4; range 78-100) in ORIF ($p<0.05$). Also, the third month after the surgery ($p>0.05$), QuickDASH score was 100 in IMNK and 100 in ORIF, as well as the sixth month of the follow-up and the twelfth month.

DISCUSSION

Surgical treatment of distal radius or both distal bone forearm fractures is based on surgeon's experience and preference with success documented with both intramedullary nailing and plate and screw fixation (4-6). To our knowledge, there are three previous studies comparing IMNK fixation and ORIF in the treatment of both bone forearm fractures in adolescent patients (11–13).

Two recent systematic reviews evaluating the treatment of distal radius or distal both-bone forearm fractures in children of all ages have highlighted the lack of high-level evidence guiding treatment of these common injuries (14-16). For children with a displaced distal radius fracture, the presence of a both-bone fracture, complete displacement of the distal radius and non-anatomical reduction are risk factors for re-displacement after the reduction of their initially displaced distal radius fracture. Children with one or more of these risk factors probably benefit most of the reduction combined with primary K-wire fixation (16). Two studies included in the recent meta-analysis (16) reported re-displacement rates between 9.7% and 35% after the reduction and cast immobilization of displaced distal radius fractures in children: only 61% of 313 re-displaced fractures received secondary treatment, 19.0% patients were considered to have enough potential for remodelling and received no further treatment after re-displacement; for the remaining 20.0% with a re-displaced fracture, it was not explicitly reported why secondary treatment was not deemed necessary. A reason might be that the definition for re-displacement and the indications for the secondary treatment were not similar in all studies. Also, wait and see policies are probably also based on the expectation that there is sufficient growth and the re-modelling potential in the injured bone in children (16). Finally, the fact that an association of repeat reduction with growth disturbances and worse functional outcome has been described, may have contributed to a reserved attitude towards repetitive reduction (17,18). The choice of intervention is influenced primarily by an assessment of the stability and the degree of displacement of the distal radius fracture taking into account the age of the child and the potential for re-modelling. In particular, the concept of tolerable displacement (angulation or linear displacement, or both) is useful in children's fracture practice; it describes an amount of displacement that will reliably remodel to a normal shaped and sized bone for stable fractures, predominantly buckle fractures. The main aim of the treatment is pain relief and protection, including forearm-injury (19).

The complication rate among our patients in the IMNK group was 29% compared to 12% in the ORIF group. There were no major complications in the ORIF group and 11 major complications (55%) in the IMNK group. Shah et al. noted a 20% complication rate in the IMNK group, all of which were minor (18); the ORIF group had an overall complication rate of 30%. Five of 13 complications (38%) in the ORIF group were considered major complications. In contrast, Reinhardt et al. had a similar complication rate in both patient groups (ORIF 66.6% vs. IMN 63.2%) (11). In their study, there was no difference in the rate of major complications between the groups. Baldwin et al. performed a meta-analysis of children of all ages and found the complication rate after ORIF to be 16.5% and 18.7% after IMNK fixation (14) and reported no difference in major complication rates and when they evaluated overall clinical outcome, the rates of poor outcomes were 13.2% for IMNK and 3.6% for ORIF; IMNK type, patient age, open fractures, and fracture location were not found to be associated with the likelihood of a complication.

The evaluated radiographic parameters included the post- operative fracture angulation, post-operative fracture displacement, and post-operative radial bow. Both IMNK fixation and ORIF resulted in post-operative fracture angulation that was not statistically different. ORIF resulted in almost no post-operative displacement at the fracture site (6).

In conclusion, the treatment of adolescent distal radius or forearm fractures remains challenging as highlighted by the relatively high complication rate across multiple studies. One challenge facing the physician is the choice of surgical technique and fixation method, which will be influenced by individual experience and preference. In our study, plate and screw fixation more closely restores anatomy and has a trend towards the lowest re-operation rate when compared to intramedullary k wire fixation (IMNK) in our adolescent age group. There is insufficient data to recommend as a gold standard the ORIF with plate and screws, although open reduction and internal fixation may be preferred as patients approach skeletal maturity. The question of distal radius or forearm fractures in adolescents would best be answered with a prospective randomized study.

FUNDING

No specific funding was received for this study.

TRANSPARENCY DECLARATION

Conflict of interest: None to declare.

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