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Published in:
Archives of orthopaedic and trauma surgery

DOI:
10.1007/s00402-010-1071-x

Citation for published version (APA):
Kloen, P., Wiggers, J. K., & Buijze, G. A. (2010). Treatment of diaphyseal non-unions of the ulna and radius. Archives of orthopaedic and trauma surgery, 130(12), 1439-1445. DOI: 10.1007/s00402-010-1071-x

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Treatment of diaphyseal non-unions of the ulna and radius

Peter Kloen · Jim K. Wiggers · Geert A. Buijze

Received: 6 August 2009 / Published online: 9 March 2010
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Abstract

Introduction Non-unions of the forearm often cause severe dysfunction of the forearm as they affect the interosseus membrane, elbow and wrist. Treatment of these non-unions can be challenging due to poor bone stock, broken hardware, scarring and stiffness due to long-term immobilisation.

Method We retrospectively reviewed a large cohort of forearm non-unions treated by using a uniform surgical approach during a period of 33 years (1975–2008) in a single trauma centre. All non-unions were managed following the AO-principles of compression plate fixation and autologous bone grafting if needed.

Patients The study cohort consisted of 47 patients with 51 non-unions of the radius and/or ulna. The initial injury was a fracture of the diaphyseal radius and ulna in 22 patients, an isolated fracture of the diaphyseal ulna in 13, an isolated fracture of the diaphyseal radius in 5, a Monteggia fracture in 5, and a Galeazzi fracture-dislocation of the forearm in 2 patients. Index surgery for non-union consisted of open reduction and plate fixation in combination with a graft in 30 cases (59%), open reduction and plate fixation alone in 14 cases (27%), and only a graft in 7 cases (14%). The functional result was assessed in accordance to the system used by Anderson and colleagues.

Results Average follow-up time was 75 months (range 12–315 months). All non-unions healed within a median of 7 months. According to the system of Anderson and colleagues, 29 patients (62%) had an excellent result, 8 (17%) had a satisfactory result, and 10 (21%) had an unsatisfactory result. Complications were seen in six patients (13%).

Conclusion Our results show that treatment of diaphyseal forearm non-unions using classic techniques of compression plating osteosynthesis and autologous bone grafting if needed will lead to a high union rate (100% in our series). Despite clinical and radiographic bone healing, however, a substantial subset of patients will have a less than optimal functional outcome.

Keywords Non-union · Radius · Ulna · Internal fixation · Forearm

Introduction

Compression plate-and-screw fixation of diaphyseal fractures of the radius and ulna in adults has been common practice since the late 1950s. Large series have shown this technique to be straightforward with a low complication rate [1–6]. Controversies focused on bone grafting for acute fractures [7–10], the type and length of the plate [5, 11, 12], and the risk of refracture after plate removal [13–16]. Benefits of plate-and-screw fixation are the ability for anatomic and secure reconstruction allowing early motion. Complications of open reduction and internal fixation of forearm function are infection, malunion, non-union, nerve injury, compartment syndrome, bleeding, formation of a synostosis, and limited function [6].

Typical rates reported for forearm non-unions in large cohort studies range between 2 and 10% [1, 5, 7, 8, 17–20]. A diaphyseal forearm non-union is disabling as it effects not only the forearm but also the elbow and wrist. Failure to reconstitute the exact relation between radius and ulna will affect the proximal and distal joints, limiting the ability to
place the hand in space [21]. Most often the non-union has a multifactorial cause combining fracture characteristics (e.g. low vs. high energy impact, comminution, location, soft tissue damage, open vs. closed), patient characteristics (age, co-morbidities) as well as surgeon-dependent causes (surgical technique and strategy).

We retrospectively reviewed a large cohort of forearm non-unions in adults treated during a period of 33 years (1975–2008) in a single trauma centre. We present their uniform surgical approach, their functional results and rates of union as well as additional surgery and complications.

Patients and methods

All patients treated in our centre for diaphyseal forearm non-unions during the 24-year period between 1975 and 1999 formed the initial cohort. They were extracted from an AO-database into which all patients for fracture care at our hospital were entered during that time. On average, 21 patients per year were treated for diaphyseal fractures of the forearm. The number of patients that was treated yearly for a non-union of the forearm declined during that period for two reasons. Firstly, our department was, and still is, a tertiary referral centre for failed fixation and/or non-unions starting in the 1970s and 1980s. Secondly, the technique of fixation became better known and union rates after primary surgery for forearm fractures improved. Additional cases between 2002 and 2008 were entered into the study cohort at admission for treatment by the senior author (P.K.). A non-union was defined as absence of healing after 4 months, or evident failure of treatment prior to that [22]. All patients with skeletal immaturity, congenital forms of non-union, or a follow-up of <12 months were excluded. As a result, 47 patients were included in the study cohort, which consisted of 35 men and 12 women with an average age of 37 years (range 16–76 years). The indications for treatment of the non-union were pain, limited function, forearm deformity and/or hardware failure.

Twenty-one fractures involved the left arm, 25 fractures involved the right arm and 1 patient fractured both arms. The mechanism of injury was a motorised vehicle accident in 26 patients, a fall in 12, and a crush injury in 9. The pattern of injury was a fracture of the diaphyseal radius and ulna in 18 patients, an isolated fracture of the diaphyseal ulna in 15, an isolated fracture of the diaphyseal radius in 7, a Monteggia fracture in 5, and a Galeazzi fracture-dislocation of the forearm in 2 patients. According to the AO classification of ulnar and radial shaft fractures [23], there were 6 type-A1, 1 type-A2, 7 type-A3, 13 type-B1, 4 type-B2, 11 type-B3, 3 type-C1, and 2 type-C2 fractures. Eighteen fractures (38%) were open; according to the system of Gustilo and Anderson [24, 25], there were six type-1, four type-2, and seven type-3A fractures. For one open fracture the Gustilo and Anderson type could not be determined. Eleven patients were polytraumatic with at least one more fracture in other areas. Ten patients had an associated nerve injury, two ulnar nerve lesions, five radial nerve lesions, a median nerve lesion, a combined radial and median nerve lesion and a brachial plexus lesion. One patient had a radial artery lesion, which was acutely repaired. The percentage of smokers was 58%. Prior treatment consisted of cast immobilisation in eight cases. Thirty-three patients received 1 previous operative treatment, which consisted of plate fixation in 22 (1 with primary grafting), external fixation in 3, and K-wires/Rush pins in 3. Five patients were converted early from a cast to plate fixation after an average of 9 days (range 4–20 days). In one patient external fixation was early switched to plate fixation and in one patient plate fixation was early switched to external fixation. Two patients underwent plate fixation twice, and one patient received an intramedullary nail twice after undergoing plate fixation twice. In one patient previous treatment was unknown. There were 51 non-unions in 47 patients, including a non-union of the radius in 16 patients, the ulna in 27 patients and of both ulna and radius in 4 patients. Four of the 18 patients that had initially broken both forearm bones produced non-unions of both radius and ulna, seven produced a non-union of the radius, and seven produced a non-union of the ulna. Four of the non-unions were classified as atrophic (8%), 13 as hypertrophic (25%) and 34 as oligotrophic (67%) [26].

The time between the injury and the index surgery that resulted in healing averaged 16 months (range 2–312 months). Sixteen surgeons were involved. Principles of surgery were consistently a thorough debridement of avital tissues, removal of failed hardware, restoration of alignment, length, rotation, stable fixation using compression if possible (tensioner device and/or lag screws), optimisation of a bone forming environment (including bone grafting if needed) allowing for early motion. Index surgery for non-union consisted of open reduction and plate fixation in combination with a graft in 30 cases (59%), open reduction and plate fixation alone in 14 cases (27%), and only a graft in 7 cases (14%). Grafting was performed in 32 cases with autogenous cancellous graft. Donor sites were the iliac crest in 24, olecranon in 7 and distal radius in 1. In four cases a tricortical iliac crest block was used and in one case a vascularised fibula graft was used. No use has been made of bone graft substitutes.

Follow-up data were obtained by retrospective review of medical records and selective invitations for a free clinical and radiographic examination when insufficient data were available. The retrospective character of the study withheld us from recording functional scores such as the DASH. The final functional result was therefore assessed in accordance
to the system used by Anderson and colleagues [1] at the most recent visit at the orthopaedic outpatient service at our institution. This scoring system, which was recently used by Ring et al. [22] in a comparable study, rates an united fracture with $<10^\circ$ loss of elbow or wrist motion and $<25\%$ loss of forearm rotation as excellent, a healed fracture with $<20^\circ$ loss of elbow or wrist motion and $<50\%$ loss of forearm rotation as satisfactory, a healed fracture with more than $30^\circ$ loss of elbow or wrist motion and more than $50\%$ loss of forearm rotation as unsatisfactory, and a malunion, non-union, or unresolved chronic osteomyelitis as failure.

**Results**

The average follow-up time was 75 months (range 12–315 months). All non-unions healed within 18 months after the index procedure (Figs. 1, 2) with a median time to union of 7 months (range 10–84 weeks). Range of motion at the most recent follow-up averaged $64^\circ$ (range $10^\circ$–$90^\circ$) for wrist flexion, $68^\circ$ (range $15^\circ$–$90^\circ$) for wrist extension, $64^\circ$ (range $0^\circ$–$80^\circ$) for pronation, $60^\circ$ (range $0^\circ$–$80^\circ$) for supination, $139^\circ$ (range $120^\circ$–$140^\circ$) for elbow flexion, and $2^\circ$ (range $0^\circ$–$50^\circ$) for elbow flexion contracture. Details on fracture type, treatment and function are summarised in Table 1.

According to the system of Anderson and colleagues 29 patients (62%) had an excellent result, 8 (17%) a satisfactory result, and 10 (21%) had an unsatisfactory result. No treatments resulted in failure. The reasons for the unsatisfactory results were limited range of motion of the wrist in eight patients, elbow stiffness in one and a median nerve lesion in one. Concerning the 18 patients that had an open fracture at the time of injury, 8 patients had an excellent result (44%), 3 patients had a satisfactory result (17%), and 7 patients had an unsatisfactory result (39%).

Complications and additional surgery

Twenty-seven patients had hardware removal after consolidation. This used to be fairly standard at our institution but it is not any more. One patient refractured his radius after hardware removal and underwent renewed plate fixation. One patient underwent manipulation under anaesthesia for wrist stiffness and one had a forearm tenolysis. Two patients had a postoperative nerve injury, of which one developed enduring meralgia paraesthetica after iliac crest bone harvesting, and one had a radial nerve palsy, which ultimately recovered over time. In two cases an infection developed at the graft donor site, one at the iliac crest site and the other at the fibula. In both cases the infections were successfully eradicated with debridement and antibiotics.

**Discussion**

The standard technique of compression plate-and-screw fixation in acute diaphyseal forearm fractures is well established [27]. Their union rate has been consistently high.

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**Fig. 1**  
**a** Anterior–posterior radiograph of an atrophic radius non-union in a 38-year-old female. She had undergone multiple previous attempts to obtain union at an outside hospital. Notice the protruding pin proximally.  
**b** Wide intra-operative exposure (Henry approach), with a 3.5-mm LCP plate on the radius. Intra-operative distraction maintaining radial length was obtained with a temporary external fixator.  
**c, d** Treatment consisted of autologous corticocancellous bone grafting and 3.5-mm LCP plate fixation. Radiographs at 15 months follow-up show a healed radius.
As many patients in our patient group were referred to us from outside hospitals, data from the original injury (e.g., soft tissue condition) and surgery were often incomplete. This precluded us to define the exact cause of failure, although we can infer this is likely to be a combination of factors including biology, biomechanics, surgical technique and co-morbidities. It is suggested in the literature that intramedullary wires, K-wires, simple lag screws or one-third tubular plates carry a high risk of providing inadequate fixation [9].

Current fixation of choice is a relatively long 3.5-mm compression plate. Most authors advise six cortices on each side of the fracture; more recently use of only four cortices on each side was suggested [12]. The choice of bone graft has historically been a topic of debate. Nicoll [29] was one of the first to report on the use of (cortico)-cancellous autograft in forearm non-unions. Numerous authors have reported on its (modified) use, as was noted in a review by Faldini and colleagues [19]. Ring and colleagues indeed showed that for atrophic non-unions with segmental defects up to 6 cm non-vascularised autogenous corticocancellous grafts leads to bony union [22]. Recently, Baldy Dos Reis and colleagues [30] showed that treatment with corticocancellous bone grafts and plate fixation for both atrophic and hypertrophic non-unions led to excellent radiological and functional outcome in their cohort of 31 patients. Petalling of both sides (1.5–2 cm) of the non-union, with opening of the medullar canal to remove the sclerotic cap using a drill is a very important aspect of the procedure. We generally take the graft from the iliac crest, if done appropriately, deformity at the donor site is negligible with a low morbidity [31]. Given a compliant well-vascularised soft tissue envelope, vascularisation of corticocancellous graft often is rapid, with incorporation of the graft within a few weeks [22].

The use of non-vascularised bone blocks has been proposed by various authors [19, 26, 29, 32–34]. Of note is that in these studies patients were often protected postoperatively in a cast for a long period.

In review of the literature, it seems that non-unions of the ulnar and radial diaphyseal non-unions is straightforward with a high success rate if “classic” principles of non-union surgery are followed. These principles are a thorough debridement of avital tissues, removal of failed hardware, restoration of alignment, length, rotation, stable fixation using compression if possible (tensioner device and/or lag screws), optimisation of a bone forming environment (including bone grafting if needed) allowing for early motion. However, despite clinical and radiological consolidation, a significant number of patients (21% in our series) might have an unsatisfactory long-term functional outcome due to limited range of motion. When limited to open fractures 39% had an unsatisfactory result.

Our results show that oligotrophic non-unions are more common than atrophic- or hypertrophic non-unions. In contrast to another report, we did not find a higher risk for the ulna than for the radius to produce a non-union in both bone fractures [28].

To the best of our knowledge, our cohort presents the largest series of forearm non-unions with a minimum of 12 months follow-up and both functional and radiological outcome in the English literature.

The involvement of 16 surgeons might suggest a wide variety of surgical detail. However, we argue that the high success rate shown in this report suggests that our described technique of treating forearm non-unions is one that is reproducible and can be circulated among surgeons.
| Age/sex | Fracture type (AO) | Open (G&A) | Non-union location | Non-union type | Time from injury to index surgery (months) | Graft | F.U. (months) | Elbow flex/ext | Forearm pro/sup | Wrist flex/ext | Result |
|---------|-------------------|------------|--------------------|----------------|------------------------------------------|-------|--------------|----------------|----------------|----------------|--------|
| 36M A1  | Ulna              | Hypertrophic | 5                  |               |                                         |       | 31           | 140/0          | 80/80          |                 | Excellent |
| 45M A1  | Ulna              | Hypertrophic | 10                 |               |                                         |       | 15           | 140/0          | 40/40          |                 | Satisfactory |
| 16F A1  | Ulna              | Hypertrophic | 312                | Olecranon     |                                         |       | 146          | 120(--15)     | 30/80          |                 | Satisfactory |
| 66F A1  | Ulna              | Hypertrophic | 9                  |               |                                         |       | 13           | 140/0          | 80/80          |                 | Excellent |
| 28M A1  | Ulna              | Hypertrophic | 3                  |               |                                         |       | 12           | 130/0          | 40/80          |                 | Excellent |
| 38M A1  | Ulna              | Hypertrophic | 6                  |               |                                         |       | 94           | 140/0          | 80/80          |                 | Excellent |
| 35M A2  | Radius            | Hypertrophic | 5                  |               |                                         |       | 72           | 140/0          | 80/80          |                 | Excellent |
| 28M A3  | Radius            | Oligotrophic | 16                 |               |                                         |       | 22           | 140/0          | 40/60          | 40/65          | Unsatisfactory |
| 50M A3  | Grade 1           | Radius     | 2                  |               |                                         |       | 13           | 140/0          | 70/70          |                 | Excellent |
| 28M A3  | Grade 1           | Radius     | 6                  | ICBG          |                                         |       | 248          | 140/0          | 80/80          |                 | Excellent |
| 38F A3  | Radius            | Atrophic   | 26                 | ICBG          |                                         |       | 15           | 140/0          | 40/80          |                 | Excellent |
| 45M A3  | Ulna              | Hypertrophic | 34                 | ICBG          |                                         |       | 55           | 140/0          | 80/80          |                 | Excellent |
| 34F A3  | Ulna              | Oligotrophic | 45                 | ICBG          |                                         |       | 84           | 140/0          | 80/80          |                 | Excellent |
| 20M A3  | Ulna              | Oligotrophic | 20                 | ICBG          |                                         |       | 34           | 140(--10)     | 70/60          |                 | Excellent |
| 50M A3  | Grade 1           | Ulna       | 2                  |               |                                         |       | 13           | 140/0          | 70/70          |                 | Excellent |
| 70M B1  | (Galeazzi)        | Radius     | 12                 | ICBG          |                                         |       | 12           | 140/0          | 80/80          |                 | Near full Excellent |
| 50M B1  | (Monteggia)       | Ulna       | Hypertrophic       | 7             | ICBG                                     |       | 70           | 140/0          | 60/60          | 60/50          | Unsatisfactory |
| 41F B1  | Ulna              | Hypertrophic | 4                  |               |                                         |       | 13           | 140/0          | 80/80          |                 | Excellent |
| 61M B1  | (Monteggia)       | Ulna       | Oligotrophic       | 13            | ICBG                                     |       | 32           | 140/0          | 80/80          |                 | Excellent |
| 42M B1  | (Monteggia)       | Ulna       | Oligotrophic       | 5             | Olecranon                                |       | 12           | 140/0          | 80/80          |                 | Excellent |
| 39F B1  | Ulna              | Oligotrophic | 3                  |               |                                         |       | 91           | 140/0          | 80/80          |                 | Excellent |
| 33F B1  | Ulna              | Oligotrophic | 30                 | ICBG block    |                                         |       | 21           | 140/0          | 80/80          |                 | Excellent |
| 18M B1  | Ulna              | Oligotrophic | 6                  | ICBG          |                                         |       | 295          | 140/0          | 70/30          |                 | N/A Satisfactory |
| 36M B1  | Ulna              | Oligotrophic | 2                  |               |                                         |       | 55           | 140/0          | 80/80          |                 | Excellent |
| 40M B1  | (Monteggia) Grade 1 | Ulna       | Oligotrophic       | 5             | ICBG                                     |       | 156          | 140/0          | 80/50          |                 | Excellent |
| 35M B1  | Grade 1           | Ulna       | Oligotrophic       | 7             |                                         |       | 13           | 140/0          | 80/80          |                 | Excellent |
| 19M B1  | (Monteggia) Grade 3A | Ulna      | Oligotrophic       | 12            | ICBG                                     |       | 63           | Limited        | Limited        | Limited         | Unsatisfactory |
| 28M B1  | Open, grade N/A   | Ulna       | Oligotrophic       | 5             | ICBG                                     |       | 177          | 140/0          | 80/80          |                 | Excellent |
| 63M B2  | Radius            | Oligotrophic | 3                  | ICBG block    |                                         |       | 52           | 140/0          | 45/0           |                 | 45/15 Unsatisfactory |
| 46M B2  | Radius            | Oligotrophic | 7                  | ICBG block    |                                         |       | 315          | 140/0          | 80/30          |                 | 70/80 Satisfactory |
| 24M B2  | (Galeazzi) Grade 2 | Radius   | Oligotrophic       | 4             | ICBG block                                |       | 25           | 140/0          | 80/80          |                 | 70/80 Excellent |
| 28M B2  | Grade 3A          | Radius     | 5                  | ICBG          |                                         |       | 40           | N/A            | 45/0           |                 | Poor Unsatisfactory |
| 21F B3  | Radius            | Hypertrophic | 7                  | Olecranon     |                                         |       | 93           | 140/0          | 80/80          |                 | 70/80 Excellent |
| 16M B3  | Grade 3A          | Radius     | 5                  | ICBG          |                                         |       | 108          | 140(--5)      | 45/0           |                 | 15/10 Unsatisfactory |
| 20F B3  | Radius            | Oligotrophic | 68                 | ICBG          |                                         |       | 174          | 140/0          | 80/50          |                 | 70/80 Excellent |
| 37M B3  | Radius            | Oligotrophic | 6                  | ICBG          |                                         |       | 310          | 140/0          | 80/80          |                 | 70/80 Excellent |
| 76F B3  | Radius            | Oligotrophic | 3                  | Radius        |                                         |       | 26           | 140/0          | 40/70          |                 | 40/40 Unsatisfactory |
| 23M B3  | Grade 3A          | Radius     | 3                  | ICBG          |                                         |       | 84           | 140/0          | 65/70          |                 | 75/50 Satisfactory |
| 38M B3  | Grade 2           | Radius     | 5                  | ICBG          |                                         |       | 113          | 130/0          | 20/45          | N/A            | Unsatisfactory |
| 16M B3  | Grade 3A          | Ulna       | 5                  | ICBG          |                                         |       | 108          | 140(--5)      | 45/0           |                 | 15/10 Unsatisfactory |
| 30M B3  | Ulna              | Oligotrophic | 14                 | Olecranon     |                                         |       | 24           | 140/0          | 50/60          | N/A            | Excellent |
| 49F B3  | Ulna              | Oligotrophic | 4                  | Olecranon     |                                         |       | 20           | 140/0          | 80/40          |                 | 70/80 Excellent |
| 22M B3  | Ulna              | Oligotrophic | 10                 | Olecranon     |                                         |       | 98           | 140/0          | 80/80          |                 | 70/80 Excellent |
| 50M B3  | Grade 2           | Ulna       | 12                 | ICBG          |                                         |       | 13           | 140/0          | 40/40          |                 | 70/80 Satisfactory |
| 23M B3  | Grade 3A          | Ulna       | 3                  | ICBG          |                                         |       | 84           | 140/0          | 65/70          |                 | 75/50 Satisfactory |
| 38M B3  | Grade 2           | Ulna       | 5                  | ICBG          |                                         |       | 25           | 130/0          | 45/0           |                 | 15/30 Unsatisfactory |
intramedullary nailing of non-unions of the diaphysis of ulna or radius should not be considered an alternative to plate fixation [38]. Their functional outcome indicated inferior results to plate-and-screw techniques.

In summary, classic AO technique with adequate debridement, eradication of infection and stable fixation using compression (using lag screws, eccentric drilling and/or AO tensioner device) will lead to successful healing of the vast majority of forearm non-unions. Longer plates (3.5 mm) with a high plate-span/screw ratio are preferred. In case of osseous defects up to 6 cm, autogenous corticocancellous bone grafts are recommended [22]. For larger defects free tissue transfer should be considered. Despite a very high chance of obtaining clinical and radiological healing of the non-union, patients should be informed that long-term functional outcome might be disappointing as was shown in this cohort in 21%.

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