The biomechanical potential of the bone graft in the proximal ulna non-union surgery

Giuseppe Rollo¹
Michele Bisaccia²
Raffaele Franzese³
Paolo Pichieri¹
Marco Filipponi³
Marco Giaracuni¹
David Gómez-Garrido⁴
Umberto Ripani⁵
Enio De Cruto¹
Gorizio Pieretti³
Luigi Meccariello¹

¹ Department of Orthopedics and Traumatology, “Vito Fazzi” Hospital, Lecce, Italy
² Division of Orthopedics and Trauma Surgery, University of Perugia, “S. Maria della Misericordia” Hospital, Perugia, Italy
³ Multidisciplinary Department of Medical-Surgical and Dental Specialties, University of Campania “Luigi Vanvitelli”, Naples, Italy
⁴ Department of Orthopaedics and Traumatology, Orthopaedic and Traumatology Unit, Hospital Quirón Salud Toledo and Hospital Solimat Toledo, Toledo, Spain
⁵ Division of Anesthesia, Analgesia and Intensive Care and Pain Therapy. Department of Emergency and Major Trauma, “Ospedali Riuniti di Ancona”, Ancona, Italy

Address for correspondence:
Luigi Meccariello
Department of Orthopedics and Traumatology
“Vito Fazzi” Hospital, Piazzetta Filippo Muratore,
Block: A- Floor: V
Lecce, Italy
E-mail: drlordmec@gmail.com

Summary

Introduction. Non-union after operative treatment of a displaced fracture of the olecranon or osteotomy are very uncommon and usually related to patient noncompliance and/or insufficient surgical technique with implant failure. The purpose of this study is to evaluate the outcomes our plate-and-bone-strut-allograft technique with bone chip augmentation in the management of olecranon aseptic non-unions.

Materials and methods. We included 22 patients with distal third humeral non-unions. All non-unions were classified according to the ASAMI classification for long bones. All cases were performed through a posterior approach to the ulna, in which the non-union focus was localized, the intramedullary channel was drilled, and the non-union was stabilized by a Locking Compression Plate combined with a strut bone allograft placed laterally to the olecranons and bone chips in the non-union gap. Postoperative fluoroscopy was used to assess reduction as well as dynamic testing of the elbow. To study the bone healing on radiographs, we used the Non-Union Scoring System (NUSS) retrospectively. In the follow-up of cases, we applied the duration of surgery, objective quality of life through Mayo Elbow Score system (MES), and subjective quality of life and elbow function measured by Oxford Elbow Score (OES) as criteria. Bone alignment was examined by X-ray and bone union through the radiographic union score by Radiographic Union Score for metaepiphyses. All patients underwent the same rehabilitation protocol of 12 weeks.

Results. Full bone healing without complications was achieved in all 22 patients. The average period of union was 94.48 days. After healing the alignment was perfect in 16 cases, a valgus deformation remained in 4 cases, and a varus deformation remained in 2 cases. At twelve months after surgery, all the patients reached full recovery with the average range of flexion-extension at 111.56° (±29.33°) and of pro-supination at 162.34° (±12.8°). The objective and quality of life measured by MES 12 months after surgery were good-excellent.

Conclusion. Given the excellent postoperative results in full bone healing, the recovery of the range of motion, and the lack of major complications seen in this study, we find that LCP plating with supporting allograft is a good choice of treatment in the cases of non-union in the olecranon non-union surgical revision.

KEY WORDS: aseptic non union; bone strut allograft; complications; osteosynthesis; plate; breakage; olecranon; outcomes.

Introduction

Non-union after operative treatment of a displaced fracture of the olecranon or osteotomy are very uncommon and usually related to patient noncompliance and/or insufficient surgical technique with implant failure. Non-unions of the proximal ulna are associated with complex injury patterns such as anterior or posterior fracture-dislocations of the olecranon and posterior Monteggia fractures. In particular, posterior Monteggia injuries in adults typically occur in older women with poor bone quality. They can be difficult to secure resulting in inadequate plate fixation and subsequent non-union (1). Factors favouring non-union can be patient related or therapy-related. To increase chance of union, therapy has to be optimal. Several types of treatment can be proposed for olecranon fractures or osteotomies (conservative, intramedullary nailing, tension bending, k wire, plating, external fixation) (2). In every case, a precise technique and proper indication are essential for success (2-6). Non-union, displacement, and fixation failure can result in complications after olecranon fractures or olecra-
non’s osteotomies (2-6). Bone grafting and augmentation have had good results in olecranon’s non-union (2-6). The purpose of this study is to evaluate the outcomes our plate-and-bone-strut-allograft technique with bone chip augmentation in the management of olecranon aseptic non-unions.

Materials and methods

Patient selection and follow-up

All patients at our institution with an olecranon non-union were screened with the following exclusion criteria: hematological or oncological disease, acute or chronic systemic infections, ASAMI non-union classifications type A (aseptic non-union without bone defect) and C (infected non-union) (7), age under 18 years, bone metabolism disease, and rheumatoid disease.

At the outpatient clinic, all patients were informed in a clear and comprehensive way of the type of treatment 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 the informed consent form. All patients underwent the same rehabilitation protocol (see Rehabilitation Protocol). To quantify bone healing on radiographs, we used the Non-Union Scoring System (NUSS) (8).

The outcomes during follow-up were surgical data, adverse events during follow-up, objective elbow function measured by range of motion and the Mayo Elbow Score (MES) (9) and the subjective quality of life and the elbow function measured by Oxford Elbow Score (OES) (10). The criteria to evaluate the patients groups bone healing were: all the Author readers utilized the RUSM (Radiographic Union Score for Metaepiphysariss) score provided by Litrenta et al. (11). RUSM provides four component scores: cortical bridging, cortical disappearance, trabecular consolidation, and trabecular disappearance. Each component can be scored from 1 to 3. Similarly, the two trabecular indices were scored from 1 to 3, each based on consolidation for one of the indices, and fracture line disappearance for the other. The overall RUSM score therefore ranged from a minimum of 10 to a maximum of 30.

Pain visual analogic score (VAS) was collected the same day when the X-rays were taken (12). The evaluation endpoint was set at 12 months after surgery, yet follow-up was prolonged to the last outpatient visit to December 2018.

Statistical analysis

Cohen’s kappa coefficient (κ) is a statistic which measures inter-rater agreement for qualitative (categorical) items. Through this parameter we calculated the concordance between different qualitative values of outcomes, bone healing, and the anatomical and biomechanical axis of the humerus from the radiological point of view.

Surgical technique

We used a standardised surgical technique performed by the surgeons. The patient was positioned prone with the arm on a radiolucent supportor a padded post. Either option gives maximum freedom to approach the proximal ulna. The approach was performed using the posterolateral approach (PMA) (13). The posterior midline skin incision was made from begin 5 cm proximal to the olecranon in the midline of the posterior distal humerus, curving medially around the tip of the olecranon and it will be along the ulnar shaft.

Full thickness skin flaps were elevated, and the ulnar nerve was identified, mobilized, and protected if it did not put anteriorly. We disengaged the flexor muscles, respecting the muscles for easy reinsertion, from the ulnar crest to a length equal to the bone strut to be implanted.

After having exposed the non-union focus, we removed the previous implant and surgically reduced the fracture (Figure 1 C). We reamed the intramedullary shaft (Figure 1 D). The strut allograft (decellularized donor proximal ulna shaft) was prepared on a separate table and a modelled plate for proximal ulna was temporarily fixed with a K-wire. Cortical screws were used to hold the plate-and-bone-strut-allograft, which was placed in such way to support the anterior humeral hinge (Figure 1 E). Then we drilled the proximal and ulnar shaft to implant a locking screw for stability for fixation of the allograft to the proximal and ulnar shaft. Bone chips were grafted and impacted as an augmentation inside the humeral shaft. We placed the bone chips mixed with Putty® Biocollagen Crunch bone paste (Biogen®, Bioteck™, Arcugnano, Vicenza, Italy) in the cortical gap. At the end of the surgery, the reduction result was inspected by fluoroscopy in three different views (Figure 1 F) and by dynamic testing of the elbow and wrist. The flexor was reattached with the muscle side facing the sutures at its insertion using absorbable sutures. Following the muscle reattachment, we closed the subcutaneous layer with absorbable sutures and skin with metal staples. For the first three postoperative weeks, all patients were placed in a rein cast from proximal humerus to the metacarpals with the elbow flexed in 90 degrees.

Results

We treated 22 patients with proximal ulna non-union. The demographic data of the enrolled patients are described in Table 1. The mean total follow-up was 30.8 (±7.86; 12-96) months (Table 2). All 22 patients demonstrated wound healing within 21 days. During the whole follow-up we had no superficial of deep infections and no material failure. In an skinny patient we had to remove the hardware because he had pain when he put his elbow on the table. This pain was due to the thin skin.

After complete bone healing, the elbow alignment was normal in 20 patients (77%), valgus in 5 patients (19%), and varus in 1 patient (4%) (Table 2). At 12 months after surgery, the arcs of flexion-extension and pro-supination averaged 111.56° and 162.34°, respectively. The objective quality of life and elbow function, measured by MES, before the trauma was on average 94 points (range 90-100). At the moment of non-union with eventual failure of orthopedic hardware, the MES averaged 20 (range 8-40). After 1, 3 and 6 months from the revision surgery the MES scores averaged 32 (range 24-62), 66 (range 46-86) and 80 (range 54-100) respectively. At final follow-up at twelve months the average MES score was 88 (range 68-100) (Figure 2).

The subjective quality and elbow function measured by OES, was on average 96 points (range 90-100) before the first trauma. At the moment of non-union with eventual failure of orthopedic hardware, the OES averaged 26 (range 12-46). After 1, 3 and 6 months from the revision surgery the OES scores averaged 36 (range 22-48), 68 (range 30-84) and 78 (range 56-100) respectively. At final follow-up at twelve months the average OES score was 90 (range 52-100) (Figure 3).
up to 30 degrees of extension deficit. At Week 5 the brace was placed in full elbow flexion, with up to 20 degrees of extension deficit, and at week 6 the brace was adjusted to full elbow flexion, with up to 10 degrees of extension deficit.

**Strengthening program**
The postoperative strengthening program included single plane active ROM elbow flexion, extension, supination, and pronation.

**Week 7-11**
The patients were allowed full range of motion of the elbow, and could discontinue the brace if they demonstrated adequate motor control. The patients could begin composite motions (i.e. extension with pronation). If at 8 weeks postoperatively the patient had significant range of motion deficits, the therapist could consider more aggressive management after consultation with the referring surgeon.

The Average Correlation of clinical-radiographic results and patient outcomes was high according Cohen κ: 0.8293±0.0731 (Figures 4, 5).

**Rehabilitation protocol**
The purpose of our protocol is to provide the clinician with an orientation of the postoperative course of rehabilitation, in order to support a standardized physiotherapy program for the entire patient population.

**Week 1-3**
During the first three postoperative weeks, the patients wore a resin cast from the humerus to the metacarpals, with the elbow flexed at 90 degrees.

**Week 4-6**
After the first three weeks, the patients received a Hinged Elbow Brace. At Week 4 the brace was placed in full elbow flexion, with up to 20 degrees of extension deficit.

**Figure 1 A-F** - A 49-year-old woman, operated two years earlier for a Monteggia’s injury, with metallic ulna cerclage and capillectomy (A, B). After two years Aseptic non-union with decomposition of the fragments of the proximal ulna see CT (C, D). The patient is operated according to our technique (E, F).
Discussion

Some technical errors in the management of proximal ulnar fractures are blamed for the development of non-union. These include casting an unstable fracture, plating with an insufficient number of screws in the proximal fragment, and underestimation of a coronoid fracture or an anterior cortical comminution as a stress riser on a dorsally applied plate (14). Other factors include treating a very proximal Monteggia fracture as an olecranon fracture with an insufficient tension band wiring or an intramedullary screw, and early excision of the head of the radius before consolidation of the ulna (14). In most of these situations, bone grafting plus revision plating with the same rationale would eventually be doomed to failure. Olecranon fracture fixation is

Strengthening program

A progressive active-resistance exercise program was initiated for elbow flexion, extension, supination, and pronation.

Week 12

At week 12 the Hinged Elbow Brace was removed with standard procedure. At this time, the patients were able to initiate light upper extremity weight training.

Strengthening program

12 weeks marked the initiation of an endurance program that simulated desired work activities/requirements. The program focused on stimulation of the elbow and shoulder range of motion, strength and coordination.

Table 1 - Description, epidemiology, type of fracture and etc. of the population.

<table>
<thead>
<tr>
<th>Description of population</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Patients</td>
<td>22</td>
</tr>
<tr>
<td>Average age, years</td>
<td>52.58 (±27.68)</td>
</tr>
<tr>
<td>Gender Ratio (male:female)</td>
<td>1.44 (13:9)</td>
</tr>
<tr>
<td>Previous Type of Accident</td>
<td>Fall From Height: 6 (27.27%) Traffic Accident: 6 (27.27%) Aggression: 2 (9.09%) Work Accident: 8 (36.37%)</td>
</tr>
<tr>
<td>Previous Type of Distal fractures according Schatzker’s Classification</td>
<td>A: 1 (4.55%) B: 2 (9.09%) C: 3 (13.64%) D: 5 (22.72%) E: 5 (22.72%) F: 6 (27.28%)</td>
</tr>
<tr>
<td>Orthopedic device used in the surgery for the osteosynthesis of the first proximal humeral fracture</td>
<td>Tension Bending wire: 3 (13.64%) Cannulated Screws: 3 (13.64%) Locking Plate: 4 (18.18%) Olecranon Plate: 7 (31.82%) Olecranon Tension Blade: 5 (22.72%)</td>
</tr>
<tr>
<td>Occupation</td>
<td>Agricultural Industry: 6 (27.27%) Industrial Sector: 10 (45.46%) Tertiary Industry: 6 (27.27%)</td>
</tr>
<tr>
<td>Injured Upper Limb Side</td>
<td>Right: 8 (36.37%) Left: 14 (63.63%)</td>
</tr>
<tr>
<td>Dominant Injured Upper Limb</td>
<td>Right: 4 (18.18%) Left: 5 (22.72%)</td>
</tr>
<tr>
<td>Average Non Union Scoring System (SD)</td>
<td>52.68 (±9.84)</td>
</tr>
<tr>
<td>Range Non Union Scoring System</td>
<td>21-65</td>
</tr>
</tbody>
</table>
The biomechanical potential of the bone graft in the proximal ulna non-union surgery

Table 2 - This results summary table of the surgical technique is safe (we did not have any complications), allows rapid consolidation and high inter-rater agreement between clinical-radiographic results and patients outcomes.

<table>
<thead>
<tr>
<th>Description of Results</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Follow-up in months (SD; range)</td>
<td>30.8 (±7.86; 12-96).</td>
</tr>
<tr>
<td>Average surgical time in minutes (SD; range)</td>
<td>74.24 (±19.26; 61-115)</td>
</tr>
<tr>
<td>RBC Transfused in IU (SD; range)</td>
<td>0.2 (±0.1; 0-3)</td>
</tr>
<tr>
<td>Wound Closure in days</td>
<td>21</td>
</tr>
<tr>
<td>Average Time Of Bone Healing In Days Registered By X-Rays (SD; range)</td>
<td>94.48 (±7.57; 63-105)</td>
</tr>
<tr>
<td>Type of Elbow Alignment</td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td>16 (76.92%)</td>
</tr>
<tr>
<td>Valgus</td>
<td>4 (19.23%)</td>
</tr>
<tr>
<td>Varus</td>
<td>2 (3.85%)</td>
</tr>
<tr>
<td>Arc of flexion-extension (SD; Range)</td>
<td>111.56° (±29.33°; 85°-180°)</td>
</tr>
<tr>
<td>Arc of prono-supination (SD; Range)</td>
<td>162.34° (±12.8°; 100°-180°)</td>
</tr>
<tr>
<td>Average correlation between clinical-radiographic results and patients outcomes (SD)</td>
<td>κ: 0.8293±0.0731</td>
</tr>
</tbody>
</table>

Figure 2 - Trend of Objective Mayo Elbow Score (MES) from pre trauma to 1 year after the revision surgery. At twelfth month from the revision, the outcomes according MES were average excellent.

most frequently complicated by hardware-related irritation and pain in the post-operative period due to the naturally thin layer of subcutaneous tissue about the dorsal surface of the elbow (15).

Open reduction and plate osteosynthesis of displaced olecranon fractures allows for anatomic reduction, stable fixation, and early motion, and this treatment method has historically yielded good results. The use of locked plating for these injuries has yielded good results, and may provide improved fixation in very comminuted fractures or osteoporotic bone (16). The cost of locking plates however is consider-

ably greater than non-locking plate systems. The application of the plate on the dorsal surface of the ulna functions more effectively as a tension band under flexion forces (17). The Olecranon Sled device was found to have no difference in biomechanical strength from that of the standard intramedullary screw with tension band construct. The Olecranon Sled was also found to be significantly less prominent while being faster to implant than the intramedullary screw (18). Han et al. (19) and Jupiter (20) reported high union rates using vascularized bone grafts, which is a valid technique but requires a longer surgical time and specialized equip-
healing process of the bone even in bones with no load like those of the upper limb (21-26). Despite significant advances in surgical technique and a constantly expanding armamentarium of reconstructive options, adequate fixation of metalwork in bone loss remains a problem (27). Joint re-

ment. Instead Faldini et al. (21) proposed in forearm aspetic non-union the fibular allograft with good or excellent result. From our clinical experience we have found that the allograft structure in the various segments gives an excellent stability to the mechanical metal system, allowing a greater healing process of the bone even in bones with no load like those of the upper limb (21-26). Despite significant advances in surgical technique and a constantly expanding armamentarium of reconstructive options, adequate fixation of metalwork in bone loss remains a problem (27). Joint re-

Figure 3 - Trend of Subjective Oxford Elbow Score (OES) from pre trauma to 1 year after the revision surgery. At twelfth month from the revision, the outcomes according OES were average excellent.

Figure 4 - Gaussian distribution of correlation between, clinical-radiographic results and patients outcomes was high according Cohen κ: 0.8293±0.0731.
The biomechanical potential of the bone graft in the proximal ulna non-union surgery

Conclusion

We suggest the use of our plate-and-bone-strut-allograft technique with bone chip augmentation technique in proximal ulnar aseptic non-unions to restore the biomechanics, support the elbow axis and to maintain reduction until complete fracture healing. This technique has shown it can produce a high percentage of unions without adverse events related to the surgery itself or the materials used.

Acknowledgements

None.

ORCID: 0000-0002-3669-189X

Conflict of interest statement

All Authors disclose any financial and personal relationships with other people or organizations that could inappropriately influence (bias) their work. Examples of poten-
tional conflicts of interest include employment, consultancies, stock ownership, honoraria, paid expert testimony, patent applications/registrations, and grants or other funding.

Conflict of interest statement

All Authors disclose any financial and personal relationships with other people or organizations that could inappropriately influence (bias) their work. Examples of potential conflicts of interest include employment, consultancies, stock ownership, honoraria, paid expert testimony, patent applications/registrations, and grants or other funding.

Human and animal right

For this type of study is not required any statement relating to studies on humans and animals. All patients gave the informed consent prior being included into the study. All procedures involving human participants were in accordance with the 1964 Helsinki declaration and its later amendments.

References

The biomechanical potential of the bone graft in the proximal ulna non-union surgery
