

## Two-stage bone-and-strut technique in the treatment of septic non-unions in the upper limb

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### ABSTRACT

**Aim** To report the results of a two-stage reconstruction of septic non-unions of the upper limb using the bone-and-strut technique with a follow-up of more than two years.

**Methods** A total of 19 patients (12 males and seven females; age 27 to 85 years) were included in this cohort study. The evaluation endpoint was set at 24 months. Radiographic union, Quick Disabilities of the Arm, Shoulder and Hand (QuickDASH) scores, pain and return to work were assessed. All patients were treated with debridement and antibiotic therapy. At a second stage, the non-union focus was filled with a cancellous bone allograft. Stability was provided using a locking plate and a bone strut.

**Results** After 24 months, the QuickDASH scores improved from a median of 28 (interquartile range, 13 – 35 points), to a median of 78 (interquartile range, 70 – 89 points). Mean pain scores improved from 8.1 (range, 0.3-10) to 0.6 (range 0-2). Radiographic and clinical union was seen in all patients. The majority of patients returned to work or previous activities when retired. A new neurological deficit, recurrence of infection, or other surgery-related adverse events were not observed.

**Conclusion** The two-stage bone-and-strut technique is a safe and effective technique in the treatment of septic non-unions of the upper limb. The union rate is high, the complication rate is acceptable and return-to-work is high. Recurrence of infectious sequelae during a follow-up period of at least two years was not seen. The patient-reported outcomes increased significantly.

**Key words:** fractures, ununited; infections; surgical procedures, operative

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## INTRODUCTION

Infected non-unions of long bones of the upper extremity are uncommon, and their successful treatment represents a great challenge to an orthopaedic surgeon. Bowen and Widmaier found that patients with three or more immune system compromising factors and an open fracture to have an incidence of infection of 30% (1). Other risk factors are bone and soft-tissue loss, inadequate fixation, poor vascularity of the bony fragments, prolonged wound drainage and formation of a sinus, osteopenia, pre-existent osteomyelitis, adjacent joint stiffness, deformities or length discrepancies, previous surgery on the fractured bone and resistant polybacterial infection (2–4).

Non-unions with a concomitant infection pose the dual challenge of eradicating infection while trying to obtain union in an unfavourable environment for bone healing. Issues include soft tissue damage from open fractures and prior surgery, bone loss and segmental loss, instability and multiple medical comorbidities (1,3). Two strategies are possible; first, to obtain union of the fracture followed by removal of infected osteosynthesis, or second, by removing the infected material and to create optimal circumstances for bone healing with a two-stage treatment (3,5,6).

In the two-stage treatment of septic non-unions, infections are usually treated with removal of all foreign material and devitalized tissue followed by parenteral or oral antibiotics; sometimes antibiotic-impregnated polymethylmethacrylate spacers are used to maintain bone length for subsequent surgeries and to achieve high doses of antibiotics at the non-union site (2–4, 7,8). The second stage of treatment consists of obtaining best biological and mechanical circumstances for union, as in aseptic non-unions; internal fixation, bone graft and soft tissue reconstruction (9–13). When this type of reconstruction is not favourable or possible, bone transport with distraction osteogenesis is another possible solution (14).

The aim of this study was to report the outcomes of the patients treated of the two-stage reconstruction of septic non-unions of the upper limb with a follow-up of more than two years using the bone-and-strut technique.

## PATIENTS AND METHODS

### Patients and study design

At the Vito Fazzi Hospital, Lecce, Italy (a tertiary referral centre for non-unions in Italy), 19 patients with upper extremity septic non-unions were enrolled after excluding patients with an Association for the Study and Application of the Method of Ilizarov (ASAMI) nonunion classification type A or B, and the age of less than 18 years (15). Inclusion took place between 2005 and 2019. Median age at presentation was 37 years (interquartile range 37–47 years), and only one patient was retired. The follow-up had a median duration of 32 months (range 24–156 months).

Pre-operatively, all patients were informed in a clear and comprehensive way about the type of treatment and other possible surgical and conservative alternatives possible in their specific case. Patients were treated according to the ethical standards of the Helsinki Declaration, and were invited to read, understand and sign an informed consent form regarding their surgery.

The Azienda Sanitaria Locale (ASL) Lecce (Italy) Ethical Committee approved this research.

### Methods

First, the septic focus was debrided, and temporary stability to the limb was provided according to the location of the non-union: external fixation, a cast, a polymethylmethacrylate spacer, or a combination when necessary. Cultures were taken at the first debridement surgery and prophylactic antibiotics were administered to the patient after a representative sample was obtained. A personalized scheme of antibiotics was provided according to the culture results, and consisted of at least 6 weeks of antibiotic administration. Then, an antibiotic-free interval was used to see whether the patients remained non-infectious.

When clinical and laboratory results (C-reactive protein, leucocyte count) remained satisfactory, the second surgical step proceeded where temporary fixation was removed and the non-union focus was again debrided, and filled with cancellous bone allograft. Stability was provided using a locking plate, connected to a bone strut on the opposite side for maximal rigidity. This plate-and-strut technique is in use at our centre

for aseptic non-unions (9,12,13). Post-operatively, the patients underwent a personalized rehabilitation protocol with a physiotherapist.

To quantify the non-union severity the Non-Union Scoring System (NUSS) in retrospective mode was used (16). Bone union was measured using the radiographic union score as it described (RUS) (17).

Other aspects of the follow-up were the occurrence of adverse events and the subjective quality of life measured with the Quick Disabilities of the Arm, Shoulder and Hand (QuickDASH). Pain was measured with the visual analogue scale (VAS) with scores ranging from 0 (no pain at all) to 10 (worst pain imaginable). In the case of humeral fractures, alignment was qualified by rotation, alignment and length. In the case of elbow fractures, the trochleo-capitellar angle was evaluated (18). For forearm fractures, alignment, rotation and length were scored.

### Statistical analysis

The evaluation endpoint of the treatment of septic non-unions was set at 24 months after surgery to monitor for long-term adverse events, such as low-grade infections. At this follow-up moment, radiographic union, QuickDASH scores, pain and return to work were assessed. The correlation between radiographic union and the subjective outcomes (QuickDASH score, pain, return to work yes/no) were correlated using Cohen's kappa ( $\kappa$ ) (19).

### RESULTS

In total 19 patients were enrolled, 12 males and 7 females. Most patients had a closed primary injury; five patients had an open fracture. Nine patients had a confined upper limb injury, nine were involved in a polytrauma and one had an associated lower limb injury. The primary injuries were distributed over the humerus (nine cases), elbow joint (three cases) and forearm (seven cases), and were most often treated with open reduction and plate fixation (13 of 19 cases). Failure of the primary fixation was seen in 6 cases: five times because of excessive movement over the non-union site, and once because of a peri-implant fracture, which was complicated with a combined median, radial and ulnar nerve palsy. The NUSS score varied between 21 and 56, with a median of 27 (interquartile range 24–36 points).

With regard to the microbial cause of the non-unions, staphylococcal infections were most common (*Staphylococcus aureus*, and *Staphylococcus epidermidis* in five and two patients, respectively); *Pseudomonas aeruginosa* in five, *Escherichia coli* and *Proteus mirabilis* in three patients each, and *Klebsiella pneumoniae* in one patient. The duration of infectious symptoms varied between 1–24 months, with a median duration of 5 months (interquartile range 5–9 months).

During the first stage, 16 patients received an antibiotic-loaded polymethylmethacrylate spacer (in five patients it was combined with external fixation for additional stability). Three patients received a cast (forearm non-unions) and one patient received an external fixator only (humeral shaft fracture). The second stage was performed after 2 to 6 months (median 3 months). Seventeen patients received an allograft, and two patients a peroneal autograft because of the location. The peroneal autograft was used in ulna fractures to promote bone healing by addition of living cells to the fracture site because of the notorious possibility of ulnar non-unions. However, two patients had associated injuries of the lower extremities and an autograft was not possible without acceptable extra morbidity.

Regarding the functional outcomes, at the 2-year follow-up, the QuickDASH scores improved from a median of 28 points at time of non-union (interquartile range 13–35 points), to a median of 78 (interquartile range 70–89 points). Mean pain scores were significantly reduced with a decline from 8.1 (range 0.3–10) during the non-union situation, to 3.4 (range 0.2–6) one month after surgery and to 0.6 (range 0–2) after one year. The majority of patients returned to work (or previous activities when retired) without limitations; 11 without limitation, 7 with limitations. The patient with combined nerve injury did not return to work, as he was retired and incapable of performing activities of daily life. During follow-up, we did not observe new neurological deficits, recurrence of infection, nor other surgery-related adverse events.

### DISCUSSION

In this study we presented the bone-and-strut method as a treatment for septic non-unions in different sites of the upper limb. All patients were at first debrided for infection control, and later

Table 1. Characteristics of 19 patients treated of the two-stage reconstruction of septic non-unions of the upper limb

Patient	Gender	Age (years)	Side	Site of fracture	Follow-up (months)	Occupation	Associated injury	Closed/open fracture	Non-union	NUSS at osteosynthesis	Septic symptoms duration (months)	Hardware failure	Neurological Injury	Bacterial agent
1	M	56	R	Humerus S	60	Seller	None	Closed	32	Plate	6	Screws	-	<i>S. aureus</i>
2	F	56	L	Humerus S	48	Homemaker	Polytrauma	Open	42	External fixator	5	-	-	<i>K. pneumoniae</i>
3	M	48	L	Humerus S	37	Police officer	None	Closed	34	Plate	5	Plate	Radial nerve	<i>S. epidermidis</i>
4	M	27	L	Humerus S	29	Farmer	Polytrauma	Closed	26	Nail	5	D Screws	-	<i>P. aeruginosa</i>
5	F	48	R	Humerus S	24	Metal workman	None	Closed	40	Plate	7	-	-	<i>S. epidermidis</i>
6	F	85	L	Humerus D	32	Retired	None	Closed	56	Plate	2	Perimplant fracture	Median, ulnar and radial nerve palsy	<i>E. coli</i>
7	F	47	L	Humerus D	28	Truck driver	None	Closed	23	Plate	5	-	-	<i>P. aeruginosa</i>
8	M	27	R	Humerus D	24	Student	None	Closed	21	Plate	2	-	-	<i>P. aeruginosa</i>
9	M	38	L	Humerus D	24	Building workman	None	Open	22	K wire	5	-	-	<i>P. mirabilis</i>
10	M	31	L	Elbow	144	Building workman	None	Open	38	K wires	1	Second surgery plate	-	<i>S. aureus</i>
11	F	46	R	Elbow	24	Retired	None	Closed	24	Plate	5	-	Ulnar nerve	<i>P. aeruginosa</i>
12	M	47	R	Elbow	24	Plumber	Polytrauma	Closed	27	Plate	10	-	-	<i>P. mirabilis</i>
13	M	33	L	Ulna P	36	Building workman	Polytrauma	Open	26	Plate and cerclage	2	-	-	<i>P. aeruginosa</i>
14	M	36	R	Ulna P	32	Carpenter	Lower limbs	Closed	34	Plate	11	-	-	<i>S. aureus</i>
15	F	58	L	Ulna P	24	Student	Polytrauma	Closed	23	Plate	9	-	-	<i>E. coli</i>
16	M	56	R	Ulna S	24	Building workman	Polytrauma	Closed	37	Plate	8	-	-	<i>S. aureus</i>
17	F	43	L	Radius D	156	Teacher	Polytrauma	Closed	28	Plate	24	-	-	<i>S. aureus</i>
18	M	55	R	Radius D	48	Plumber	Polytrauma	Open	23	External fixator	12	-	-	<i>E. coli</i>
19	M	56	L	Radius D	33	Carpenter	Polytrauma	Closed	26	Plate	8	-	-	<i>P. mirabilis</i>

NSSU, Non-Union Scoring System; F, female; M, male; L, Left; R, Right; D, distal; P, proximal; S, shaft; *S. aureus*, *Staphylococcus aureus*; *K. pneumoniae*, *Klebsellia pneumoniae*; *S. epidermidis*, *Staphylococcus epidermidis*; *P. aeruginosa*, *Pseudomonas aeruginosa*; *E. coli*, *Escherichia coli*; *P. mirabilis*, *Proteus mirabilis*;

**Table 2. Surgical and follow-up outcome for 19 patients treated of the two-stage reconstruction of septic non-unions of the upper limb**

Patient	Type of first step	NUSS after first step	Months between first and second step	Type of second step	Radiologic reduction	Bone healing (months)	QDASH before initial trauma	QDASH with septic non-union	QDASH one year after second step	Return to work	Correlation between clinical and radiographic results
1	Cemented spacer	62	3	P+Al	Anatomic	6	100	10	88	With limitations	0.81
2	Cemented spacer	72	2	P+Al	Anatomic	5	100	12	92	Fully	0.86
3	Cemented spacer	64	6	P+Al	Anatomic	4	100	14	84	With limitations	0.70
4	EF	46	4	P+Al	Satisfactory	4	100	14	82	Fully	0.72
5	Cemented spacer	64	3	P+Al	Anatomic	3	100	16	90	With limitations	0.88
6	Cemented spacer	78	3	P+Al	Anatomic	4	78	0	0	No	0.11
7	Cemented spacer	55	4	P+Al	Anatomic	5	90	24	76	With limitations	0.76
8	Cemented spacer	26	5	P+Al	Good	6	100	38	84	With limitations	0.80
9	Cemented spacer	29	4	P+Al	Good	5	100	36	72	With limitations	0.74
10	Cemented spacer	84	3	Art+P+Al	Satisfactory	2	96	0	64	With limitations	0.64
11	Cemented spacer	44	4	P+Al	Anatomic	4	82	0	60	With limitations	0.77
12	Cemented spacer+EF	67	3	P+Al	Good	3	100	28	62	Fully	0.78
13	Cemented spacer EF	72	3	P+Per	Good	8	100	34	76	With limitations	0.81
14	Cemented spacer+EF	54	2	P+Al	Anatomic	4	98	40	72	With limitations	0.79
15	Cemented spacer+EF	66	3	P+Per	Good	5	98	42	68	Fully	0.63
16	Cemented spacer+EF	68	4	P+Al	Anatomic	6	100	34	78	With limitations	0.77
17(Fig.1)	Cast	71	2	P+Al	Anatomic	2	100	34	100	Fully	1
18	Cast	64	4	P+Al	Anatomic	3	100	32	100	Fully	1
19	Cast	66	3	P+Al	Anatomic	3	100	36	96	Fully	0.92

NUSSU, Non-Union Scoring System; QDASH, Quick Disabilities of the Arm, Shoulder and Hand; P, plate; Al, allograft; EF, external fixator; Art, arthrodesis; Per, peroneous autograft; ADL, activities of daily living

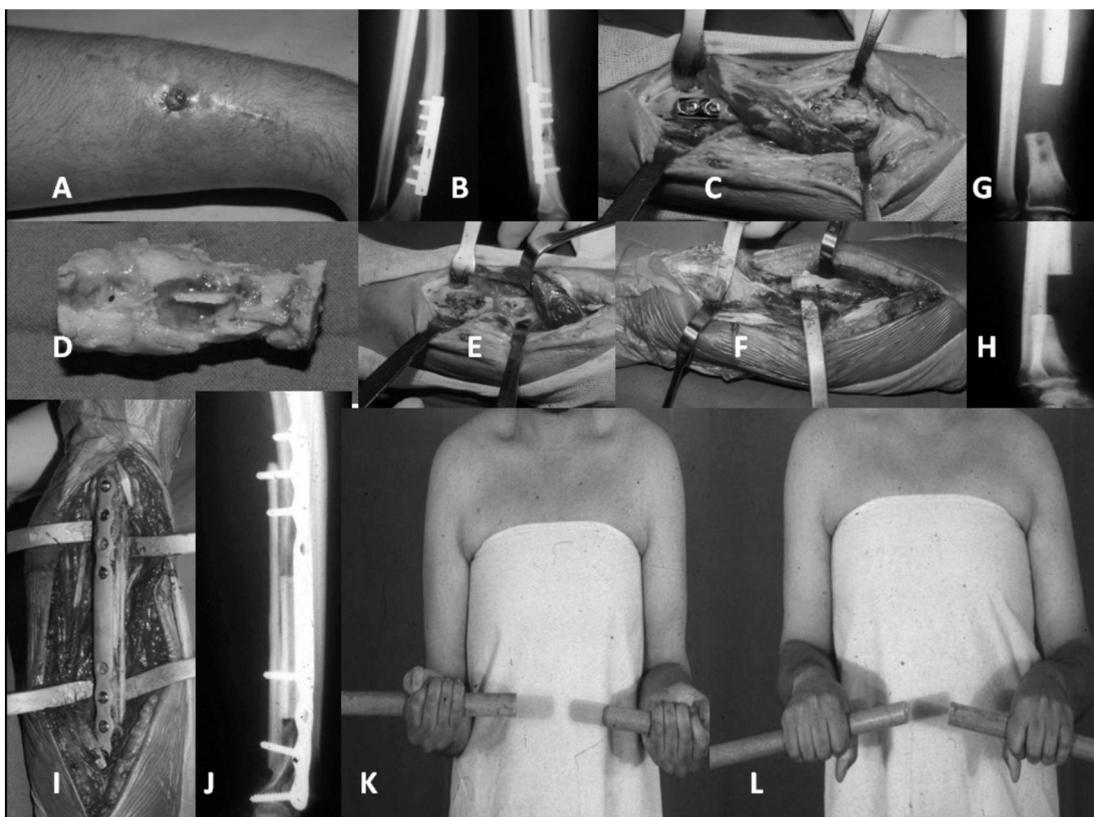
stability and bone stock was offered to achieve union. As after the first stage of infection component was eliminated, the second stage was equivalent to the treatment of aseptic non-unions at our centre, which is used in other centres as well (7,12,13). The Masquelet technique, which uses the same concept of debridement and membrane induction before final reconstruction without adding a bone strut, can also be used for septic non-unions of the upper limb (20). The main advantage of our bone-strut-technique is that additional stability and bone stock was provided using bone graft, which in our opinion provides more biological impulses for fracture healing.

The bacteria causing the non-union in our cohort were comparable to other similar cohorts with non-unions of the upper limb (7,20). The antibacterial treatment in our cohort consisted of local control by debridement and removal of all sequestrae, followed by long (intravenous) antibiotic treatment. This approach is used generally to treat infections after fractures and supported by international experts in order to treat infections and to prevent chronic osteomyelitis (5,6). However, the skin and subcutaneous tissue have to be healed completely before definitive reconstruction; otherwise, a secondary (wound) problem might occur and the treatment fails. Therefore, the time

to proceed to the second step seems long in our cohort, yet preliminary stability was provided for using a cast or external fixator, and patients were motivated enough to wait for optimal soft tissue recovery to minimize chances of failure.

Return to work is one of the factors we believe is highly important for these young patients who work with a median age of 37 years. In our group all patients without pre-existing nerve injury could return to work. Of those returning to work, 39% needed adjustments. In previous literature, return to normal activities of daily living within 90 days after the initial trauma was a predisposing factor for return to work (21). However, this 90-day period had already passed for the patients visiting our referral centre, and therefore, the rate of return-to-work in our cohort still seems satisfactory.

The functional and clinical results after two years with a relatively small interquartile range are promising, and reflect the motivation of these young patients to undergo the long trajectory after an infection. The outcomes are comparable to similar studies (7). The patient-reported outcomes improved significantly after the whole treatment to an acceptable level. Half of the patients had initially an associated trauma, with almost all of those being a polytrauma. As the septic non-unions concerned the upper limb, the activities of



**Figure 1.** Female patient operated two years before presentation, with a plate fixation of a radial shaft fracture on the left side, with a fistula (A) because of a septic non-union (B) distal radius shaft fracture on the left side, with presence of a fistula (A) and a septic non-union (B). After debridement (C) and wide resection of the septic non-union (D-F) a cast was provided. Post-operative radiographs show complete resection of avital bone (G, H). After 2 months, osteosynthesis with the plate and bone-and strut technique was performed, using an allograft (I, J). After two years, excellent functional results were obtained (K, L) (Meccariello L, 2018)

daily life were more compromised than mobility. When radiographic signs of union (measured with radiographic union scale), and the patient related outcomes (measured with the QuickDASH) were correlated, a high kappa value was seen. This means that when patients were allowed to perform more activities with their arm (based on consolidation on radiographical imaging) they also started to use this arm more, resulting in better QuickDASH scores. One patient who was not able to perform any activities because of nerve injury, scored a low correlation because he did not functionally improve, in contrast to the radiographic images. Therefore, patients' related outcomes are of high importance in our opinion and not only radiographic outcomes.

In conclusion, the two-stage bone-and-strut technique proved to be a successful treatment of septic non-unions of the upper limb without recurrence of infectious sequelae during a follow-up period of two years. The patient-reported outcomes had increased to a satisfactory level after two years of follow-up and with a high percentage of return-to-work. Therefore, we would recommend our two-stage bone-and-strut technique in these cases of high-demand, young patients with septic non-unions of the upper limb.

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#### TRANSPARENCY DECLARATION

Conflict of interest: None to declare.

## REFERENCES

1. Bowen TR, Widmaier JC. Host classification predicts infection after open fracture. *Clin Orthop Relat Res* 2005; (433):205–11.
2. Allende C, Mangupli M, Bagliardelli J, Diaz P, Allende BT. Infected nonunions of long bones of the upper extremity: staged reconstruction using polymethylmethacrylate and bone graft impregnated with antibiotics. *Chir Organi Mov* 2009; 93:137–42.
3. Struijs PAA, Poolman RW, Bhandari M. Infected nonunion of the long bones. *J Orthop Trauma* 2007; 21:507–11.
4. Hanssen AD. Local antibiotic delivery vehicles in the treatment of musculoskeletal infection. *Clin Orthop Relat Res* 2005; (437):91–6.
5. Metsemakers WJ, Morgenstern M, Senneville E, Borens O, Govaert GAM, Onsea J, Depypere M, Richards RG, Trampuz A, Verhofstad MHJ, Kates SL, Raschke M, Martin A McNally<sup>13</sup>, Obremskey WT, Fracture-Related Infection (FRI) group. General treatment principles for fracture-related infection: recommendations from an international expert group. *Arch Orthop Trauma Surg* 2020; 140:1013–27.
6. Metsemakers WJ, Kuehl R, Moriarty TF, Richards RG, Verhofstad MHJ, Borens O, Kates S, Morgenstern M. Infection after fracture fixation: Current surgical and microbiological concepts. *Injury* 2018; 49:511–22.
7. Perna F, Pilla F, Nanni M, Berti L, Lullini G, Traina F, Faldini C. Two-stage surgical treatment for septic non-union of the forearm. *World J Orthop* 2017; 8:471–7.
8. Julka A, Ozer K. Infected nonunion of the upper extremity. *J Hand Surg*. 2013; 38:2244–6.
9. Moroni A, Caja VL, Sabato C, Rollo G, Zinghi G. Composite bone grafting and plate fixation for the treatment of nonunions of the forearm with segmental bone loss: a report of eight cases. *J Orthop Trauma* 1995; 9:419–26.
10. Moroni A, Rollo G, Guzzardella M, Zinghi G. Surgical treatment of isolated forearm non-union with segmental bone loss. *Injury* 1997; 28:497–504.
11. Rollo G, Pichierri P, Marsilio A, Filipponi M, Bisaccia M, Meccariello L. The challenge of nonunion after osteosynthesis of the clavicle: Is it a biomechanical or infection problem? *Clin Cases Miner Bone Metab* 2017; 14:372–8.
12. Rollo G, Rotini R, Pichierri P, Giaracuni M, Stasi A, Macchiarola L, Bisaccia M, Meccariello L. Grafting and fixation of proximal humeral aseptic non union: a prospective case series. *Clin Cases Miner Bone Metab* 2017; 14:298–304.
13. Rollo G, Prkić A, Pichierri P, Eygendaal D, Bisaccia M, Filipponi M, Giaracuni M, Hitov P, Tanovski K, Meccariello L. Plate-and-bone-strut fixation of distal third humeral shaft aseptic non-unions: a consecutive case series. *J Clin Orthop Trauma* 2019; 10:127–32.
14. Ebied A, Elseedy A. Treatment of infected nonunion of forearm bones by ring external fixator. *Egypt Orthop J* 2018; 53:341–7.
15. Paley D, Catagni MA, Argani F, Villa A, Battista Benedetto G, Cattaneo R. Ilizarov treatment of tibial nonunions with bone loss. *Clin Orthop Relat Res* 1989; 241:146–65.
16. Calori GM, Colombo M, Mazza EL, Mazzola S, Malagoli E, Marelli N, Corradi A. Validation of the Non-Union Scoring System in 300 long bone non-unions. *Injury* 2014; 45:S93–7.
17. Whelan DB, Bhandari M, Stephen D, Kreder H, Mcke MD, Zdero R, Schemitsch EH. Development of the radiographic union score for tibial fractures for the assessment of tibial fracture healing after intramedullary fixation. *J Trauma* 2010; 68:629–32.
18. Rollo G, Rotini R, Eygendaal D, Pichierri P, Bisaccia M, Prkić A, Stasi A, Meccariello L. Effect of trochleocapitellar index on adult patient-reported outcomes after noncomminuted intra-articular distal humeral fractures. *J Shoulder Elb Surg* 2018; 27:1326–32.
19. Landis JR, Koch GG. The measurement of observer agreement for categorical data. *Biometrics* 1977; 33:159.
20. Raven TF, Moghaddam A, Ermisch C, Westhauser F, Heller R, Bruckner T, Schmidmaier G. Use of Masquelet technique in treatment of septic and atrophic fracture nonunion. *Injury* 2019; 50:40–54.
21. Murgatroyd DF, Harris IA, Tran Y, Cameron ID. Predictors of return to work following motor vehicle related orthopaedic trauma. *BMC Musculoskelet Disord* 2016; 17:171