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Judet osteoperiosteal decortication for treatment of non-union: The Cornwall experience

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ABSTRACT

Background: The treatment of non union can be challenging with a variety of surgical options available to achieve bone consolidation. Robert Judet first described a method of osteo-periosteal decortication in 1963. He stated that by elevating cortical chips that remain attached to the periosteum and overlying soft tissues surrounding the site of non-union, combined with mechanical support, the bone consolidated. Despite excellent results presented in 2008 of 99% union rates with a mean delay of 8 months, the technique has not yet become popularised. We aim to show that Judet's method of decortication can achieve good results in the management of failure of union in a hospital other than Judet's.

Methods: Retrospective analysis was performed from December 2002 to December 2008 of 40 cases in 39 patients of osteoperiosteal decortication for fracture non-union. Concurrent stabilisation was with internal fixation only. All procedures were performed by one surgeon (MN) using the Judet technique after learning the technique in the originators hospital. A preoperative non union scoring system was also used to assess its use in predicting persistent non-union.

Results: Union was successfully achieved in 36 of the 39 surviving cases (92.3%) after a median delay of 8 months (range 3–47, SD 9.2) Twenty-six patients (65%) achieved union following the decortication procedure without subsequent operations. Factors such as open fracture and smoking did not have a statistically significant effect on union. The mean number of procedures following decortication was 0.68 (range 0–4). Metalwork failure occurred in 11 cases (28%), the majority in femoral decortications ($n = 9$, 82%). The femur was the site of all persistent non unions in the series. Three patients had superficial infections and two had deep infections. The pre-operative non union scoring system (0–100) means were noticeably worse for the persistent non union group 42.0 (20–46) compared with the union group 31.0 (range 4–52).

Conclusions: Osteoperiosteal decortication remains a highly effective surgical technique in the management of failed fracture union. The non union scoring system is a reliable predictor of persistent non union after this type of surgery.

Clinical relevance: Relevant to general trauma orthopaedic surgeon and specialist orthopaedic surgeons with an interest in fracture non-union.

Introduction

Non-union presents a significant problem to orthopaedic surgeons, requiring lengthy, technical and often expensive treatments. Furthermore it is associated with significant morbidity, including reduced function, increased pain, degenerative joint disease and psychosocial problems including inability to work and mental health deterioration. A number of surgical solutions have been devised with considerable progress and improvement in outcomes. These include internal and external fixation, bone grafting, bone transport with distraction osteo-modelling and decortication techniques.

Robert Judet first described his method of osteoperiosteal decortication in 1962 and published his results in 1972[1] (see Figs. 1–3). He stated that faster and firmer healing of pseudarthroses could be achieved by surrounding the fracture site in bone chips from the ununited bone itself, as long as the bone chips remained attached to their blood supply. The method describes using a sharp, heavy chisel to elevate cortical chips, maintaining

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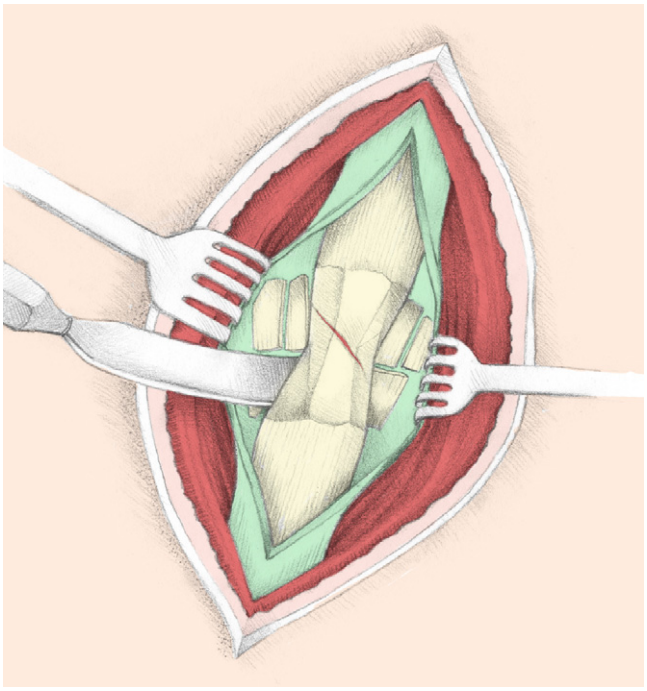

Fig. 1. Fracture site exposed by chisel leaving bone flakes attached to periosteum.

their periosteal attachment and hence blood supply. We use a 10 mm and 25 mm stainless steel chisel which is sharpened after each case. An incision is made down to the bone, through the periosteum. Chips 1–3 mm thick are elevated for 5–10 cm proximal and distal to the fracture site and for 60–75% of the bone's circumference. The underlying bone can then be debrided or osteotomised as necessary before internal fixation and suturing of the soft tissue envelope to ensure that the bone graft is approximated over the fracture site. Through this method the

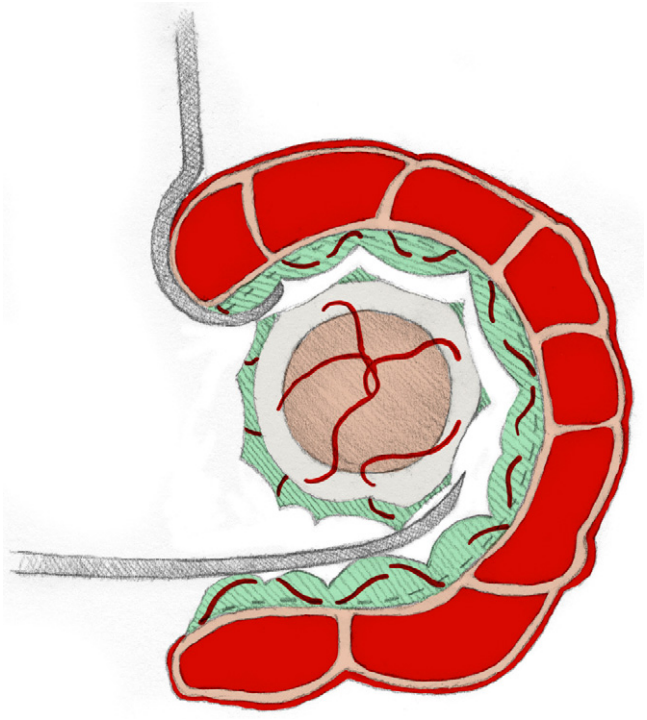

Fig. 2. Fracture site exposed by chisel leaving bone flakes attached to periosteum.

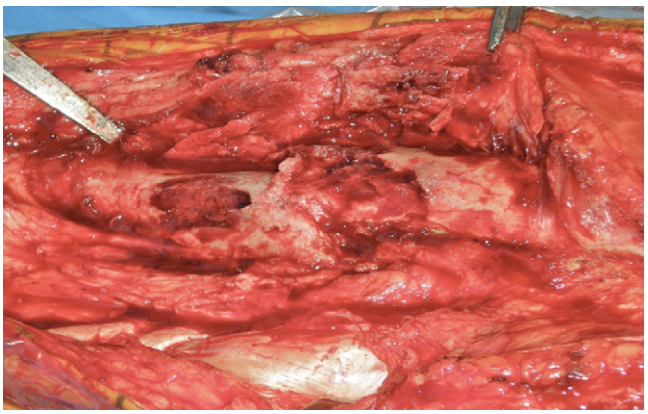

Fig. 3. Intra-operative picture of femoral non-union decortication.

osteoprogenitor cells are stimulated into increased osteogenesis and union is achieved. The latest study to be reported by the Judet group in 2008 demonstrated successful union in 99% of 297 patients within 8 months of undergoing decortication.[2]

There is no universally accepted definition for non union. It has been defined as the cessation of reparative processes without bone healing,[3] or by the absence of progression toward bone union when assessed radiologically for a period of 3 months.[4] According to AO principles, a non-union is declared between 6 and 8 months from the fracture where there is no evidence of bone healing, while others have defined non-union as existing after an interval of 9 months without healing, during which therapeutic measures have been attempted.[5]

The aetiology of non-union is multifactorial but can be broadly divided into 2 groups of factors, local and systemic, as summarised by Perumal and Roberts. Local factors include vascular integrity, presence of infection, biomechanical stability, bone contact and the magnitude of the initial injury. Many of these can be detrimentally affected iatrogenically. Systemic factors include age, nutritional state, co-morbidities (particularly diabetes mellitus and osteoporosis) and drugs (especially NSAIDs and nicotine).

Weber and Cech typed non-unions as one of atrophic, hypertrophic or oligotrophic.[6] Atrophic non-union is thought to relate to poorly vascularised bone, with a subsequent inability to produce osteocytes and therefore poor healing. Radiographically there is little or no callus around a fracture gap filled with fibrous tissue. Hypertrophic nonunion is linked to inadequate stability and appears to have an adequate vascular supply. Radiographically there is normal or increased callus formation with a persistent fracture gap.[7] Oligotrophic non-union is a state whereby no callus forms despite an adequate vascular supply, demonstrated through cross-sectional imaging or at operation. It is typically seen after major displacement of a fracture, e.g. traumatic fragment distraction or inaccurate fixation. Radiologically there is no callus formation and after 8–12 weeks resorption can be seen at the bone ends.[8] In our experience there is frequently separation of the bone ends by viable muscle in this situation.

Very often nonunions arise despite adequate fixation in an environment that should allow healing. Bone grafting, both donor[9] and synthetic[10,11] have been described in these situations to help stimulate union. However with Judet's technique autologous local bone grafting automatically occurs with the procedure in the form of the vascularised bone chips attached to the periosteum forming a 'bone graft jacket' around the fracture site.

Recognising the various difficulties of managing non-unions, Calori et al. have developed a scoring system so that patients of similar complexity can be compared with one another.[12] This produces a score out of 50, doubled to 100, which groups the

Table 1
The Calori scoring system.

		Score	Max score
The bone			50
Bone quality	Good	0	3
	Moderate (e.g. mild osteoporosis)	1	
	Poor (e.g. severe porosis or bone loss)	2	
	Very poor (necrotic, avascular, septic)	3	
Primary injury – open or closed	Closed	0	
	Open grade 1	1	5
	Open 2, 3A	3	
	Open 3B, 3C	5	
Number of previous interventions on this bone to procure healing	None	1	4
	<2	2	
	<4	3	
	>4	4	
Invasiveness of previous interventions	Minimal (closed, percutaneous, ex-fix)	0	3
	Internal – intramedullary	1	
	Internal – extramedullary	2	
	Any with bone grafting	3	
Adequacy of primary surgery	Inadequate stability	0	1
	Adequate stability	1	
Weber and Cech Group	Hypertrophic	1	5
	Oligotrophic	3	
	Atrophic	5	
Bone alignment	Non-anatomic	0	1
	Anatomic	1	
Bone defect – gap	0.5–1 cm	2	5
	1–3 cm	3	
	>3 cm	5	
Soft tissues			
Status	Intact	0	6
	Previous uneventful surgery, minor scarring	2	
	Previous treatment of sift tissue defect (local flap, multiple incisions, compartment syndrome, old sinuses)	3	
	Previous complex treatment of soft tissue defect (e.g. free flap)	4	
	Poor vascularity: absence of distal pulses, poor capillary refill, venous insufficiency	5	
	Presence of actual skin lesion/defect (e.g. ulcer, sinus, exposed bone or plate)	6	
The patient			
ASA	1, 2	0	1
	3, 4	1	
Diabetes	No	0	2
	Yes, well-controlled (HbA1c <10)	1	
	Yes, poorly controlled (HbA1c >10)	2	
Blood tests	WCC >12	1	3
	ESR >20	1	
	CRP >20	1	
Clinical infection status	Clean	0	4
	Previously infected or suspicion of infection	1	
	Septic	4	
Drugs	Steroids	1	2
	NSAIDs	1	
Smoking	No	0	5
	Yes	5	

patient into one of four groups reflecting the anticipated difficulty of managing the fracture; those who should respond to standard treatment (0–25), those requiring more specialist care (26–50), those requiring specialist care along with specialised treatments (51–75) and finally those in whom primary amputation should be considered (75–100) [Table 1].

This study aims to demonstrate that Judet's method of osteoperiosteal decortication in a group of patients with established non-unions can achieve good results within a district general United Kingdom hospital.

Materials and methods

A retrospective cohort study was performed on all cases of established clinical and radiological fracture non union treated with Judet osteoperiosteal decortication between December 2002 and December 2008. The patients were identified and data was collected from patient notes, hospital computerised records (Bluespier) and the hospital radiology Centricity Web PACS system (© GE Healthcare).

All patients underwent a standardised surgical technique as described by Judet. All operations were performed by one surgeon (MRN) who was fellowship trained in this technique by Prof. Thierry Judet. Each procedure used plate and screw osteosynthesis.

Inclusion criteria were all cases with an established non-union of a fracture treated by Judet osteoperiosteal decortication between December 2002 and December 2008. All Non union cases had ongoing clinical symptoms and radiological evidence of non-union. Exclusion criteria included any patient treated with other techniques other than or in conjunction with Judet osteoperiosteal decortication.

The primary outcome measure was time to union after undergoing the procedure. Our definition for union was based on both clinical and radiological findings, as described by Corrales et al.[13] Although they identified a lack of consensus, the most widely accepted criteria were a clinical absence of pain at the

fracture site on both palpation and weight bearing, and radiological evidence of bridging of 3 or more cortices on 2 different views.

All patients were followed-up until union was achieved. There was a minimum period of follow up of either two years or discharge following union.

We assessed the various factors that predispose to non-union and to a potential delay in achieving union following decortication from the patient notes. The following factors in particular were analysed to see if there was any difference in time to union following surgery: smoking, infected non union, open fracture, hypertrophic, atrophic or oligotrophic non-union, and fracture location.

The Calori scoring system incorporates several of these factors; we scored each patient from the time of their decortication to assess its' use in predicting those patients who went on to persistent non-union. The score is out of 100, with higher scores indicating a greater anticipated difficulty in achieving union.

The hospital research, audit and ethics department approved the study. Statistical analysis was performed by the Royal Cornwall Hospital Trust Statistics Department using SPSS software (© SPSS Inc., IBM).

Results

From December 2002 to December 2008 40 patients underwent Judet decortication for non union. The mean age was 48 years (range 19–89) with 28 (70%) males and 12 (30%) females. One patient died of unrelated causes before union was achieved. Union was achieved in 36 of the 39 remaining cases (92.3%) with a median time to union of 8 months (range 3–47, SD 9.2) from the decortication procedure. The demographics are shown in Table 2.

The mean number of procedures prior to decortication was 1.33 (range 0–3). There was no significant difference of time to union in relation to fracture location ($p = 0.321$), open status ($p = 0.524$), smoking status ($p = 0.187$), Weber–Cech type (0.483) or sex ($p = 0.74$). This compares favourably with the 2008 findings of the Judet group[2] as shown in Table 3. There were 2 deep and 3 superficial infections.

Of the 3 patients who did not achieve union, 1 tibial non-union went on to a below-knee amputation for infection and 1 persistent infected femoral non-union was referred to a specialist centre for femoral replacement surgery. A further femoral non-union remains under regular review at the time of investigation. This case has, for the purpose of the study, been included as a failure although the metalwork remains stable and there remains a possibility that the fracture will consolidate.

Fourteen (35%) of the patients required further surgical procedures subsequent to decortication. These were for the management of deep infection (3 patients) and metalwork failure (11 patients). The majority of metalwork failure occurred in the femur (9 of the 11, 82%).

The Calori et al. non-union score for the whole group was 31.55 (range 4–52). For the 36 patients who successfully united it was 31.0 (range 4–52), compared with 42.0 (20–46) for the persistent non-unions. Due to the small number of persistent non-unions it was not possible to perform useful statistical analysis on this part of the study.

Discussion

Despite its importance in modern healthcare economics, relatively little is known about the epidemiology of non unions. It is recognised that there are significant variations in non union rates between different fracture sites and patterns and with differing methods of primary treatment. Tzioupis and Giannoudis summarised the evidence for this, finding non union rates 0–80% depending on such factors as site, procedure and co-morbidity (Table 4).[14]

The objective of managing a non union is to achieve solid fracture healing with restoration of mechanical function, including limb length, alignment and adjacent joint function.[15,16] This requires correction of any biological and/or mechanical abnormality that led to the non union. Pre-requisite for bone healing is good bone stock with an intact vascular supply, healthy soft tissues and sufficient stability at the fracture site. This stability typically requires mechanical fixation, either internally or externally.

External fixation has an unclear role; Olson and Hahn felt it was rarely required, in only a minority of cases with severe soft tissue loss or damage.[17] However Biasibetti et al. found external fixation the instrument of choice, minimising risk of introducing infection

Table 2
Demographics.

Laterality	Left	15 (38%)
	Right	25 (62%)
Sex	Male	28 (70%)
	Female	12 (30%)
Smoker	No	24 (60%)
	Yes	16 (40%)
Open	No	31 (78%)
	Yes	9 (22%)
G/A classification grade	1	2 (5%)
	2	0 (0%)
	3	7 (18%)
Site	Femur	21 (53%)
	Tibia	10 (25%)
	Humerus	7 (18%)
	Clavicle	1 (3%)
	Ulna	1 (3%)
Weber–Cech type	Atrophic	24 (60%)
	Hypertrophic	12 (30%)
	Oligotrophic	4 (10%)

Table 3
Comparison with Judet's results.

	Judet group	Our study
Number of patients	297	40
Union rate	99%	92.3%
Further surgery	84%	35%
Amputations	1	1
Infections	4%	4%
Fracture location	$p = 0.97$	$p = 0.16$
Weber–Cech type	$p = 0.66$	$p = 0.83$
Open or closed	$p = 0.12$	$p = 0.69$
Smoking status	$p = 0.41$	$p = 0.26$
Infection	$p < 0.05$	$p = 0.15$

Table 4
Variable non-union rates dependent on site and method of primary treatment.

Site	Management	Non-union rates
Humerus	Nonoperative	0–13% (5 studies)
	internal fixation	0–7% (5 studies)
	IM nailing	0–33% (8 studies)
Femur	External fixation	0–12% (3 studies)
	Internal fixation	2–7% (4 studies)
	IM nailing	0–8% (9 studies)
Tibia	External fixation	14–41.4% (3 studies)
	Internal fixation	1–54% (3 studies)
	IM nailing	1–80% (5 studies)

Table 5
Comparing rates of and time to union.

Method of management	Union rate	Time to union (months)
External fixation	93%	7
Plate and screw osteosynthesis	97–100%	4–6
Intramedullary nail	93–100%	6–8
Judet decortication	97–99%	4–8
Our study	92.3%	8

whilst allowing variations of the mechanical environment.[9] Judet's original work used external fixation in virtually all cases, particularly infected non union.[1] The benefit of internal fixation with plate fixation is the lack of need for further regular wound and pin site care, lack of interference with joint movement from pins or wires but lacks the ability to make any adjustments to position once inserted.

The rates of union in our study are compared with other published evidence on the various means of managing a non union. These vary by the site and type of non union as well as the method used[2,7,9,18–22] (Table 5).

Another variable is the use of bone graft. Current evidence is divided over the use of autologous or donor bone graft or synthetic materials. Judet et al. described its use as being necessary only in cases with segmental bone defect, although they do not quantify this, stating: "the rôle of graft is . . . limited to bone filling and not to obtain continuity." Additionally, bone graft "did not change the period of consolidation."[22] Decortication is thought to work by acting as a local, vascularised bone graft thus potentially avoiding the need for further grafting, reducing morbidity and surgical time associated with autologous graft collection, or the expense of synthetic graft materials. It can alternatively be used alongside bone graft; Judet's original work advocated this in cases where the fracture ends were especially brittle or thin, or the soft tissues particularly poor, wherein the chips could not be elevated with their soft tissue attachment.[1]

Giannoudis et al. describe a diamond principle of non-union surgery.[23] This expands the traditional triangle concept of fracture healing, involving growth factors, scaffolds and mesenchymal cells, by considering the mechanical environment as well. They state that equal acknowledgment and recognition should be given to all four factors. It could be postulated that Judet's decortication technique with plate osteosynthesis is effective in regards to this theory as it incorporates both mechanical support and providing an enhanced environment for fracture healing.

Over the course of the period studied, developments in prosthesis technology meant a variety of plate materials was used, in particular steel alloy, titanium and carbon fibre. The latter conveys immense strength whilst being lightweight and inert, with minimal interference of vascular integrity. However, we have demonstrated that the major complication in our series was metalwork failure especially with femoral non-unions. This was not described as a significant problem in Judet's series. The senior author of this study hypothesised that this may be due to the high quality high strength plates used by the Judet group which were specifically made for this use by a French company. These plates are not internationally available.

Several alternative plates were used during this study with varying success. 56 of the 60 plates used were identified, including the 11 failures (in one case failure of the same type of plate occurred twice, needing a second revision procedure). Of these the most reliable was the Stryker Basic Plate which is currently the routine plate used for decortication in our unit. The Stryker Basic Plate is a large fragment 4.5 mm waisted plate without locking screw facility but allowing compression screws to be used. The Orthodynamics Carbon Fibre Plate, although very strong is reported in this study as having a high failure rate. This relates to screw failure rather than plate failure. This is felt to be due to the relatively short length of the longest diaphyseal plate resulting in a limited number of screws either side of the fracture site and screw failure occurring in a number of cases (Table 6). The introduction of heavier locking plates over the last few years has added a further option to plating of these fractures, but we do not have data yet available on whether these will be more successful or not.

Table 6
Failure rate by plate type.

Plate type	Times used	Failures	%
AO Basic Large Fragment	4	3	75
Orthodynamics Carbon Fibre Plate	6	2	33.3
Stryker AxSOS Periarticular Plate	6	0	0
Stryker Basic Large Fragment	23	2	8.7
Synthes LISS Plate	2	1	50
135° DHS Plate	1	1	100
95° Blade Plate	2	0	0
DCS	1	0	0
Other	6	2	33.3

The scoring system results suggested a difference in scores between the groups of patients that went on to union from those in the persistent non union group. This supports its use as a tool to predict those cases that are at a high risk of persistent non union. Although no statistical analysis could be performed on the score results in our study, it could be postulated from our results that those patients with a pre op score of 40 or more seem to have an increased risk of persistent non union.

Conclusion

Judet's technique of osteoperiosteal decortication combined with internal fixation of plate and screws remains a highly effective, reproducible surgical technique in the management of failed fracture union. This technique is best suited for treatment of hypertrophic non union in short oblique and transverse diaphyseal fractures which failed to unite following intramedullary nailing. The technique is not suitable for use in periarticular and intrarticular fractures nor in bones not invested with periosteal covering. It has outcomes comparable with other methods of managing non union and also has the versatility to be used in conjunction with them. The non union scoring system seems to work well as predictor of persistent non union after this surgery.

We feel that this is a relatively simple technique which can be employed in most DGH hospitals after suitable training and with access to appropriate instruments. We feel that this technique is better for patients and has a high success rate even when performed away from the originator surgeon setting.

Conflict of interest statement

There are no known conflicts of interest from any of the authors.

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