Pathological fractures of the proximal humerus treated with a proximal humeral locking plate and bone cement

H. J. Siegel, R. Lopez-Ben, J. P. Mann, B. A. Ponce

From University of Alabama at Birmingham Medical Centre, Birmingham, Alabama, United States

Bone loss secondary to primary or metastatic lesions of the proximal humerus remains a challenging surgical problem. Options include preservation of the joint with stabilisation using internal fixation or resection of the tumour with prosthetic replacement. Resection of the proximal humerus often includes the greater tuberosity and adjacent diaphysis, which may result in poor function secondary to loss of the rotator cuff and/or deltoid function. Preservation of the joint with internal fixation may reduce the time in hospital and perioperative morbidity compared with joint replacement, and result in a better functional outcome. We included 32 patients with pathological fractures of the proximal humerus in this study. Functional and radiological assessments were performed. At a mean follow-up of 17.6 months (8 to 61) there was no radiological evidence of failure of fixation. The mean revised musculoskeletal Tumour Society functional score was 94.6% (86% to 99%). There was recurrent tumour requiring further surgery in four patients (12.5%). Of the 22 patients who were employed prior to presentation all returned to work without restrictions.

The use of a locking plate combined with augmentation with cement extends the indications for salvage of the proximal humerus with good function in patients with pathological and impending pathological fractures.

Despite significant medical and surgical advances, pathological and impending pathological fractures involving the proximal humerus remain a challenging surgical problem. Osteoporosis is the leading cause of a pathological fracture in the proximal humerus.1,2 Second to the femur, the humerus is the long bone most commonly involved by metastatic bone disease.3,4 Other causes include benign lesions, such as giant cell tumours, unicameral bone cysts, aneurysmal bone cysts and malignancies such as myeloma, lymphoma and chondrosarcoma. In order to obtain the best clinical outcome local control of the tumour, a stable reconstruction and preservation of the abductor mechanism of the shoulder are required. Bone loss, extension into soft tissue, and multiple lesions in a solitary long bone must all be considered.

The use of internal fixation and augmentation with cement in pathological fractures has been well described.5-7 Traditional techniques required that the cement be placed initially, followed by screws placed either outside the cement or in holes drilled into it, which may cause fragmentation and weakening of the bone-cement interface. The use of high-profile thick plates led to soft tissue irritation and impingement, and obtaining a stable construct using a traditional fixed-angle device (i.e. a blade plate) is more technically challenging. It can result in excessive surgical time and early failure.5-7 Use of a low-profile locking plate allows multidirectional placement of the screws and may allow stable fixation and use of the locking screws to reinforce the bone-cement construct. Modern forms of treatment including advances in chemotherapy, bisphosphonates, radiation and more aggressive local removal of the lesion with high-speed burrs, have been used to help reduce the incidence of local recurrence of the tumour.8 Resection of the humerus with endoprosthetic reconstruction has gained popularity in recent years for the management of destructive lesions of the proximal humerus,8 but use of the proximal humerus plate and cement augmentation allows more of these patients to be treated successfully, with potential for a better functional outcome.

Several recent reports have shown a significant benefit with the use of locking plates in distal femoral fractures, periprosthetic femoral fractures, osteoporotic fractures in long bones and fractures of the proximal humerus.9-12 Biomechanical analysis has demonstrated the superior stability of locked plates over standard...
non-locking plates and intramedullary nailing in the proximal humerus. However, there is a paucity of literature regarding the use of locking plates in orthopaedic oncology. This study includes 32 patients with pathological fractures of the proximal humerus due to metastatic bone disease, myeloma, and primary benign bone tumours treated with intralesional resection followed by reconstruction with a proximal humeral locking plate and augmentation with cement.

**Materials and Methods**

Between December 2003 and December 2007, 32 consecutive patients with an impending or complete pathological fracture involving the proximal humerus were treated by intralesional resection and a proximal locking plate with cement augmentation at a university-based musculoskeletal oncology centre. There were 13 women and 19 men, with a mean age of 52.1 years (38 to 79), and a mean follow-up of 17.6 months (8 to 61). There were 17 with metastatic bone disease (seven lung, four breast, four renal, two thyroid); four with a plasmacytoma; two with a lymphoma of bone; nine with primary bone tumours (five solitary giant cell tumour; two low-grade chondrosarcoma; two aneurysmal bone cyst with an associated giant cell tumour).

Their medical records were reviewed for demographic data, the medical history, the histological diagnosis, imaging reports and peri-operative complications. Wound healing was assessed at two- or four-weeks when the presence or absence of dehiscence, drainage and/or swelling was recorded. All patients had anteroposterior scapular, transscapular lateral, and axillary lateral radiographs taken before operation and at each follow-up visit. Radiographs were analysed to determine post-operative alignment, the position of the plate and recurrence of the tumour (Fig. 1). Pre-operative imaging included radiographs in all patients, MRI in 26, bone scans in 16 and CT in six. Each imaging study was reviewed pre-operatively by a musculoskeletal radiologist and an orthopaedic oncologist (HS, RL). The revised Musculoskeletal Tumor Society (MSTS) functional outcomes score was completed for all patients.

The decision to operate on impending fractures was based on the criteria of Mirels. Impending or non-displaced fractures were present in 18 patients and 14 had a displaced fracture. Proximal Humeral Internal Locking Systems (Synthes, West Chester, Pennsylvania) and Simplex cement (Stryker, Mahwah, New Jersey) were used in all the patients. A proximal humeral endoprosthesis was available in case adequate stability could not be obtained with the locking plate or if there was significant loss of articular cartilage that was not appreciated during pre-operative planning.

**Surgical procedure.** The operation was performed with the patient under general anaesthesia, and all received prophylactic intravenous antibiotics prior to and for 24 hours after the procedure. The patients were positioned supine on a radiolucent operating table, and the adequacy of anteroposterior and axillary lateral fluoroscopic imaging was confirmed before draping.

A biopsy was obtained through a longitudinal incision over the anterior third of the deltoid immediately adjacent to the deltopectoral interval, in order to minimise damage to the axillary nerve. The anterior deltoid was divided in line with its muscle fibres and small bone window created with either a burr or a curette. A frozen section was performed in 23 patients to confirm the pre-operative diagnosis. The operative exposure was extended and a bone window enlarged in order to visualise the lesion and the fracture. Curettes, rongeurs and a high-speed burr were used to remove the invasive tissue inside the bone and the cavity was then pulse lavaged and inspected to confirm that the remaining bone looked normal and viable. The proximal humeral locking plate was then positioned on the lateral cortex and held in place manually or with K-wires. Initially, a non-locking bicortical screw was placed into the oblong hole. Appropriate superior or inferior adjustments were made to position the plate so that it would not cause soft tissue impingement, and so that the proximal locking screws would be evenly distributed throughout the humeral head. The screws were inserted into the head over guide-wires to determine their length, with the aim that the screw tips remain 5 mm from the subchondral bone. Proximal locking screws were placed in all the holes and

---

**Fig. 1**

Pre-operative radiograph of a pathological fracture involving the proximal humerus. The patient was diagnosed with multiple myeloma. A large lytic lesion is seen replacing the surgical neck, with extension to the articular surface.
checked for length on orthogonal fluoroscopic views. In
the bone cavity locking screws were placed to form a lat-
tice for cementation (Fig. 2). Additional locking screws
were then positioned in the proximal humerus diaphysis.
The shoulder was brought through a full range of move-
ment to check the stability of the fracture and to ensure
that there was no soft tissue impingement.

The bone cavity was then filled with Simplex cement
with a doughy consistency (Fig. 3). Once the cement had
set, the wound was irrigated and a drain placed beneath the
deltoid, which was repaired with absorbable sutures. None
of the patients underwent pre-operative embolisation of the
tumour. A pre-operative interscalene block was used in
21 of 32 patients, and post-operatively a percutaneous con-
tinuous local anaesthetic pump, On Q (I-FLOW, Lake
Forest, California) was used in 11.

The shoulder was then filled with Simplex cement
with a doughy consistency (Fig. 3). Once the cement had
set, the wound was irrigated and a drain placed beneath the
deltoid, which was repaired with absorbable sutures. None
of the patients underwent pre-operative embolisation of the
tumour. A pre-operative interscalene block was used in
21 of 32 patients, and post-operatively a percutaneous con-
tinuous local anaesthetic pump, On Q (I-FLOW, Lake
Forest, California) was used in 11.

The shoulder was immobilised in a sling post-operatively
and the patient instructed to begin independent gentle active
and active-assisted exercises within five days of the
procedure. This activity was progressed to passive stretch-
ing and gravity-resistance exercises at two weeks, and unre-
stricted exercises with formal physiotherapy were usually
started at four weeks. Patients were instructed to wear the
sling at all times for the first two weeks, except when per-
forming exercises and when bathing.

**Statistical analysis.** Fisher’s exact test was used to examine
the effect of radiation on wound healing and functional
outcome. Chi-squared analysis was used to examine the
effect of the size of the lesion, above or below the mean
value of 7 cm, on radiological outcome, and also to exam-
ine whether there was a difference in functional outcome
between an impending or a complete pathological fracture.
A p value of < 0.05 was considered significant.

**Results**

The 32 patients with pathological fractures of the proximal
humerus were treated with intralesional removal, cementa-
tion and internal fixation using a Synthes proximal humeral
locking plate. The bone lesions were measured on orthogo-
nal conventional radiographs and, when available, MRI
and/or CT. Their mean size was 7 cm (5.5 to 14). The sur-
gical neck was the most common site of fracture. The
majority of the fractures were minimally or not displaced.
In those patients with impending fractures, surgical treat-
ment was recommended based on the classification of
Mirels. The lesion was in the epiphysis in six patients, the
 metaphysis in all, the diaphysis in 14, and the epiphysis and
diaphysis in eight. Severe pain was the most common pre-
senting symptom. Two patients, both with impending frac-
tures, had swelling and shoulder stiffness.

All of the patients with a pathological fracture had pain
following a low-impact injury. Mechanisms of injury
included opening a jar, lifting a suitcase, closing a door and
pushing up from a seated position. Needle biopsies were
performed on 12 of 14 patients with impending fractures.
An open biopsy was carried out on all patients with dis-
placed fractures. A frozen section was performed at the
time of surgery in all displaced fractures to confirm the
diagnosis, and in two of the 14 impending fractures. The
two lesions suspected to be cartilaginous had an open
biopsy at the time of surgery to confirm that cartilage was
present and to exclude a high-grade sarcoma.
These were no intra-operative complications. The mean blood loss was 420 ml (100 to 900). No intra-operative blood transfusions were required, but two patients received 2 units each during their hospital stay. The mean hospital stay was for 1.3 days (1 to 4). The mean operative time was 63 minutes (41 to 122). Operative time was recorded from the skin incision to the application of dressings, and when applicable the time for frozen section was subtracted from the operative time.

The patients with metastatic disease, lymphoma and myeloma were treated with post-operative external beam radiation between two and four weeks post-operatively. There was no statistically significant difference in post-operative healing and functional outcome between patients who had received radiation and those who did not (p = 0.11). Patients with displaced fractures stayed longer in hospital than those with impending and non-displaced fractures (1.8 and 1.1 days, respectively). There was no statistically significant difference in functional outcome between patients with lesions > 7 cm and those with smaller lesions.

The revised MSTS functional outcome score17 was recorded at six months' follow-up in all patients; 20 completed a 12-month survey; 11 a 24-month survey, and six a 36-month survey. One patient completed a survey at 60 months. The mean functional score at final follow-up was 94.6% (86% to 99%) (Table I). Of the 32 patients, 22 were employed at the time of presentation. All 22 were able to return to their prior employment without restriction at a mean of 1.4 months (1 to 3) post-operatively.

Radiological evidence of recurrent tumour was noted in four of 32 patients (12.5%), two within the first six months (one renal, one lymphoma), one after nine months (myeloma) and one at 18 months (giant cell tumour). The fixation remained stable in all four, with no radiological evidence of failure. Two of these had an additional curettage and cementation procedure with retention of the locking plate, and one with recurrence of a giant cell tumour after 18 months was converted to an allograft prosthetic composite because of avascular necrosis of the humeral head, with recurrence in the greater tuberosity. The remaining 28 patients at a mean follow-up of 19.1 months (11 to 61) did not show radiological evidence of recurrence or of failure of fixation.

Intermittent mild pain associated with abduction > 90° was observed in eight patients which was probably indicative of impingement. All were treated successfully with

**Table I. Revised Musculoskeletal Tumour Society functional outcomes**

<table>
<thead>
<tr>
<th>Patient</th>
<th>Primary</th>
<th>Follow-up (months)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>1</td>
<td>Plasmacytoma</td>
<td>86</td>
</tr>
<tr>
<td>2</td>
<td>Thyroid</td>
<td>86</td>
</tr>
<tr>
<td>3</td>
<td>Lung</td>
<td>90</td>
</tr>
<tr>
<td>4</td>
<td>Giant cell</td>
<td>92</td>
</tr>
<tr>
<td>5</td>
<td>Breast</td>
<td>87</td>
</tr>
<tr>
<td>6</td>
<td>Lung</td>
<td>93</td>
</tr>
<tr>
<td>7</td>
<td>Giant cell</td>
<td>88</td>
</tr>
<tr>
<td>8</td>
<td>Lung</td>
<td>98</td>
</tr>
<tr>
<td>9</td>
<td>Breast</td>
<td>90</td>
</tr>
<tr>
<td>10</td>
<td>Breast</td>
<td>93</td>
</tr>
<tr>
<td>11</td>
<td>Giant cell</td>
<td>91</td>
</tr>
<tr>
<td>12</td>
<td>Lung</td>
<td>93</td>
</tr>
<tr>
<td>13</td>
<td>Giant cell</td>
<td>91</td>
</tr>
<tr>
<td>14</td>
<td>Breast</td>
<td>90</td>
</tr>
<tr>
<td>15</td>
<td>Renal</td>
<td>89</td>
</tr>
<tr>
<td>16</td>
<td>Plasmacytoma</td>
<td>90</td>
</tr>
<tr>
<td>17</td>
<td>Giant cell</td>
<td>93</td>
</tr>
<tr>
<td>18</td>
<td>Renal</td>
<td>92</td>
</tr>
<tr>
<td>19</td>
<td>ABC + Giant cell</td>
<td>96</td>
</tr>
<tr>
<td>20</td>
<td>Lymphoma</td>
<td>90</td>
</tr>
<tr>
<td>21</td>
<td>Thyroid</td>
<td>88</td>
</tr>
<tr>
<td>22</td>
<td>Plasmacytoma</td>
<td>93</td>
</tr>
<tr>
<td>23</td>
<td>Giant cell</td>
<td>97</td>
</tr>
<tr>
<td>24</td>
<td>Lung</td>
<td>87</td>
</tr>
<tr>
<td>25</td>
<td>Renal</td>
<td>93</td>
</tr>
<tr>
<td>26</td>
<td>Plasmacytoma</td>
<td>90</td>
</tr>
<tr>
<td>27</td>
<td>ABC + Giant cell</td>
<td>88</td>
</tr>
<tr>
<td>28</td>
<td>Lung</td>
<td>90</td>
</tr>
<tr>
<td>29</td>
<td>Breast</td>
<td>93</td>
</tr>
<tr>
<td>30</td>
<td>Renal</td>
<td>91</td>
</tr>
<tr>
<td>31</td>
<td>Lung</td>
<td>93</td>
</tr>
<tr>
<td>32</td>
<td>Lymphoma</td>
<td>91</td>
</tr>
</tbody>
</table>
subacromial steroid injections and non-steroidal anti-inflammatory medication. This delayed onset of symptoms was thought to be associated with an increase in activity and discontinuance of formal physiotherapy. All eight patients had tumour extending into the greater tuberosity. Slight superior positioning of the plate did occur in some patients, but did not appear to be related to symptoms of impingement. Post-operative haematomas were seen in three patients, which in one required operative evacuation followed by successful healing. Deep venous thrombosis (DVT) prophylaxis was not used routinely, but patients with additional significant risk factors were treated with enoxaparin for three weeks after operation and three patients were on warfarin at the time of diagnosis. Warfarin was withheld for one week prior to surgery and restarted on the first day after operation, and two received enoxaparin (Sanofi Aventis, Bridgewater, New Jersey) during the week prior to surgery because they had had a cardiac stent placed during the previous year.

Discussion
Surgical stabilisation remains the mainstay of treatment for patients with impending and complete pathological fractures of the humerus. The benefits of operation have been well documented, but the optimal method for fixation and the supplemental use of cement remains uncertain. The current trend appears to favour replacement of the proximal humerus for destructive lesions involving the epiphysis and metaphysis, intramedullary nailing with or without cement for diaphyseal lesions, and plating with or without cement for the distal humerus. The introduction of a locking plate into orthopaedic oncology has made a significant impact. Pathological fractures which were once thought to be unsalvageable may now be treated successfully. The proximal humerus appears to be a suitable site for aggressive local control without compromising the stability or function of the shoulder joint.

Non-operative management is generally reserved for patients with extensive comorbidities, at a low risk of pathological fracture, with a short life expectancy and non-aggressive benign lesions. Radiosensitive lesions may be treated with pre- or post-operative radiation, but often this does not restore adequate bone density and may compromise fracture healing. Many patients with malignant disease are treated in the peri-operative period with chemotherapy, radiation or both. Immune and bone marrow suppression often places these patients at increased risk of infection, haematoma and wound complications. Therefore, limiting the surgical time, exposure and blood loss is probably beneficial. Some authors have recommended the use of closed intramedullary nailing, as blood loss is minimised, the soft tissue undisturbed, and the majority of the humerus is protected from future fracture. Complications have been associated with osteopenic bone, non-anatomical reduction of the fracture and inadequate fixation of the screws across the medial calcar.

Bone loss involving the proximal humerus presents a problem not found in other common sites of pathological fracture. The shoulder is primarily non-weight-bearing, and therefore the use of a load-bearing device such as intramedullary nail is not as important as in the femur. Unlike the diaphysis, the epiphyseal-metaphyseal region has a thin, fragile cortex, with little stability likely to be added by interlocking screws through an intramedullary nail. Violation of the rotator cuff may result in weakness of the shoulder and subsequent stiffness, and there is a risk of propagating the fracture while passing the nail into the intramedullary canal, spreading the tumour to a distal site and causing embolisation of fat and tumour. Cementation may be performed with intramedullary nailing but there is often a defect in the cortex which may result in soft tissue extrusion and cement fracture. A locking plate combined with cementation has the potential to produce a superior, more rigid construct with better immediate stability than an intramedullary nail. Aggressive removal of tumour may theoretically reduce the incidence of local progression and/or recurrence.

Polymethylmethacrylate cement has long been used as an adjunct to the treatment of pathological fractures with internal fixation. Compared to fixation without cement its use has been associated with less pain, earlier return of function, and less dependence on carers. The decision to place bone cement prior to or after internal fixation is determined by the preference of the surgeon. Compared to bone, methylmethacrylate is relatively radiation resistant and its exothermic reaction may have a beneficial effect on local tumour necrosis. A potential weakness associated with polymethylmethacrylate is the slowing or impairment of bony union, which is further impaired by post-operative radiation.

As shown in many studies evaluating the effects of cementation in the treatment of giant cell tumours, durable long-term results may be seen in the majority of patients who have loss of bone at the epiphysis and metaphysis of long bones. The fixed, divergent angled locked screws and the low-profile aspect of the proximal humeral locking plate is an ideal lattice for cementation without causing soft-tissue impingement. Its application is not technically difficult and is reproducible with highly predictable results. The possibility of haemorrhage in the open surgical removal of a metastatic lesion should certainly be considered, particularly in patients with thyroid and renal cell carcinoma. In patients with compromised haemodynamic reserve, pre-operative embolisation should be considered. The use of the bipolar haemosealant device has been shown to be effective in reducing bleeding in patients at-risk.

The use of a locking plate and augmentation with cement appears to extend the indications for salvage of the proximal humerus. Proximal humeral replacement remains a good option for patients with extensive involvement of the articular cartilage, and the intramedullary nail is a good option with predominantly diaphyseal involvement.
Our current management for impending and complete pathological fracture of the proximal humerus is intralesional resection with a high-speed burr under direct visual and fluoroscopic guidance, followed by placement of a proximal humeral locking plate and cement. The results of this technique are both reproducible and predictable.

Supplementary material

A further opinion by Mr H. Brownlow is available with the electronic version of this article on our website at www.jbjs.org.uk

References