An algorithm for the surgical treatment of periprosthetic fractures of the femur around a well-fixed femoral component

The use of plate-and-cable constructs to treat periprosthetic fractures around a well-fixed femoral component in total hip replacements has been reported to have high rates of failure. Our aim was to evaluate the results of a surgical treatment algorithm to use these lateral constructs reliably in Vancouver type-B1 and type-C fractures. The joint was dislocated and the stability of the femoral component was meticulously evaluated in 45 type-B1 fractures. This led to the identification of nine (20%) unstable components. The fracture was considered to be suitable for single plate-and-cable fixation by a direct reduction technique if the integrity of the medial cortex could be restored.

Union was achieved in 29 of 30 fractures (97%) at a mean of 6.4 months (3 to 30) in 29 type-B1 and five type-C fractures. Three patients developed an infection and one construct failed.

Using this algorithm plate-and-cable constructs can be used safely, but indirect reduction with minimal soft-tissue damage could lead to shorter times to union and lower rates of complications.

The treatment of periprosthetic fractures of the femur after total hip replacement (THR) remains a surgical challenge. The Vancouver classification developed by Duncan and Masri\(^1\) is the most widely used for guiding the surgeon in pre-operative planning. It has recently been further validated in a European setting.\(^2\) The stability of the femoral component in the proximal fragment is the cornerstone of this classification. Most of the published literature suggests that a loose and unstable femoral component should be revised to a long stem which bypasses the site of the fracture.\(^3,5\) Fractures with high rates of failure and with the most variable treatment options are those with the femoral component securely fixed in the proximal fragment.\(^6,7,10-13\) Therefore refinements in the algorithm for surgical treatment are needed.\(^3,4\)

Open reduction and internal fixation (ORIF) without revision of the femoral component has been successful when it remains securely fixed in the proximal fragment of the fracture. This means that Vancouver type-B1 (at the tip or around the component) and type-C fractures (distal to the component) are suitable for ORIF.\(^1,10,14,17\) Several studies have reported good results using cortical strut allograft reconstructions with or without plate fixation, making it the current treatment of choice, especially in North America.\(^18-21\) By contrast, the use of a single-plate construct has been questioned with high rates of revision of up to 34% being observed in a large series of 256 fractures.\(^5\) However, favourable results have also been reported.\(^17,22\) The rationale behind the development of plate-and-cable systems was to allow for fixation with a proximal cable without violating the implant or the cement mantle around it. Both high\(^23,24\) and low\(^6,25\) rates of failure of fixation have been reported. Underestimation of loosening of the femoral component\(^6,7\) and varus alignment of the component\(^24\) have been postulated as one explanation for the high failure rates of fixation with plates alone.

We have used a surgical treatment algorithm which was based on the Vancouver classification. We hypothesised that if the femoral component was confirmed intraoperatively to be well fixed in the proximal fragment and an anatomical reduction of the medial cortex could be achieved, then a lateral plate-and-cable construct without additional strut allografting would be adequate to treat these complex fractures.

Patients and Methods

We treated 106 periprosthetic femoral fractures in 102 patients between 1996 and 2006.
Operative technique and surgical algorithm. All the fractures were evaluated by means of a pre-operative standard anteroposterior (AP) radiograph of the pelvis and lateral views of the femur. Of these 45 were assessed pre-operatively as type B1 and 11 as type C.

In the type-B1 fractures, the hip was dislocated surgically in order to confirm intraoperatively the stability of the femoral component in the proximal fragment (Fig. 1). The direct lateral approach was used with the patient supine. The femoral component was dislocated and the acetabular component evaluated for stability and the integrity of the articulating surface. None of the acetabular components needed revision. The stability of the femoral component was tested by means of longitudinal traction, rotational torque and inspection of the cement-bone interface. Of the 45 presumed stable components nine (20%) were actually unstable and the pre-operative plan was changed to revision of the component. Of these nine unstable components, four were cemented and five were uncemented. The implant remained securely fixed to the bone in 36 hips and the fracture was regarded as suitable for ORIF. The incision was lengthened sufficiently distal to the site of the fracture. Periosteal stripping was kept to a minimum to preserve the blood supply and the linea aspera was never stripped of its soft-tissue attachments. The site of the fracture was opened to remove cement debris and the fracture held reduced by reduction forceps with the plate provisionally in place. This was always evaluated by an intraoperative radiograph. The fracture was only considered to be suitable for fixation by a lateral plate alone if the medial cortex was not comminuted and an anatomical reduction of the medial cortex could be achieved (n = 33) (Fig. 2). An additional plate or strut allograft was applied to the anterior cortex in the case of comminution of the medial cortex (n = 3). The length of the plate was measured to allow at least four bicortical fixation sites on either side of the fracture. The plate was attached to the lateral cortex, slightly more anteriorly or posteriorly, guided by the location of the femoral component in the proximal femur as evaluated on the lateral radiograph. At least four bicortical screws were used in the distal fragment. In addition, at least one site for distal cable fixation was used in oblique and spiral fractures to compress the fragments. At least four proxi-
mal fixation sites over a length of at least twice the outer cortical diameter of the femur were always used. Proximal cable fixation was employed in all cases and the screws were used to obtain rotational stability. Bicortical proximal screws were placed anterior or posterior to the femoral component with purchase in the cement mantle in the case of osteoporotic bone. Unicortical screws were used in three hips with uncemented, canal-filling components. The plate was extended proximally and one or more screws were angled into the greater or lesser trochanter. This was preferably undertaken with uncemented femoral components, or in younger patients, in order to provide rotational stability in addition to the cable fixation (n = 15, Fig. 3).

In type-C fractures, a locking plate (Less Invasive Stabilization System (LISS); Synthes, Brussels, Belgium) was used if at least four bicortical screws could be used in the proximal fragment but distal to the tip of the femoral component. A lateral plate-and-cable system with at least two fixation sites around the femoral component was used if the fracture extended high proximally and fixation around the component to obtain four proximal sites was mandatory. An additional plate or strut allograft was used in the case of comminution of the medial cortex.

Post-operatively, the patients were restricted to touch-toe weight-bearing for at least eight weeks. Weight-bearing was gradually increased, based on the radiological formation of callus. Physiotherapy, with range of movement exercises of the hip and knee, was started immediately post-operatively as well as isometric strengthening exercises of the quadriceps and hamstrings. All the patients were assessed every six weeks until union of the fracture was achieved.

### Table 1. Details of types of fracture treatment

<table>
<thead>
<tr>
<th>Fractures treated with open reduction and internal fixation (n = 47)</th>
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<tbody>
<tr>
<td>Single PCS*: 29 B1 and 5C</td>
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<tr>
<td>PCS with additional fixation: 3 B1 and 1C</td>
</tr>
<tr>
<td>Distal locking plate (LISS): 5C</td>
</tr>
<tr>
<td>Dynamic compression plate: 2 B1</td>
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<td>Locking compression plate: 2 B1</td>
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* PCS, plate-and-cable system

### Details of the patients

In total, 47 fractures were treated by ORIF using this algorithm (Fig. 1). Of these, 13 were not treated by a single plate-and-cable system and were excluded from our series for clarity and because of the low numbers of the different methods of treatment. All 13 fractures healed uneventfully except for one type C which sustained an additional type-B1 fracture above the LISS plate (Fig. 1, Table I). This left 29 type-B1 and five type-C fractures in 34 patients treated by a lateral plate-and-cable system. Of these, 32 were treated by a Dall-Miles system (Howmedica, Rutherford, New Jersey) and two by the Cable Ready system (Zimmer Inc, Warsaw, Indiana). Details of these patients are given in Table II. Their mean age was 77.1 years (49 to 94). There were 14 patients who had received a bipolar THR as treatment for a fracture of the femoral neck, 14 who had received a primary THR and six a cementless revision femoral component for loosening of the femoral component. The mean interval from the initial operation to fracture was 42.2 months (1 to 168) although this was significantly shorter if the fracture of the neck of femur was the primary indication for treatment (22.8 vs 86.9 months;
There were eight patients who sustained a type-B1 fracture within three months of surgery. In six this was caused by a fall from a standing height. Two patients who did not have a clear traumatic event were suspected of having a missed intraoperative fracture around the tip of an uncemented femoral component. All femoral components were well fixed in the proximal fragment.

The mean follow-up was 43 months (12 to 87). Clinical union was defined as full weight-bearing (with or without aids) with no or only slight occasional pain which did not compromise walking or basic daily activities. Union was defined as clinical union in the presence of radiological evidence of bone bridging in both the AP and lateral views.

Four parameters were used to evaluate the outcome of treatment namely the time to union, alignment of the fracture, the pre- and post-operative University of California, Los Angeles (UCLA) hip score and the presence of complications. Malunion was defined as > 5° of deformity at the site of the fracture in either the frontal or the sagittal plane.

Table II. Details of the 34 patients with fracture around a well-fixed femoral component which was treated by a plate-and-cable construct

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Mean (range) age in years 77.1 (49.0 to 94.0)</th>
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<tbody>
<tr>
<td>Gender</td>
<td>Female 25, Male 9</td>
</tr>
<tr>
<td>Side</td>
<td>Left 15, Right 19</td>
</tr>
<tr>
<td>THR* indication</td>
<td>Fractured neck of femur 14, Osteoarthritis 13, Avascular necrosis 1, Revision arthroplasty 6</td>
</tr>
<tr>
<td>Trauma mechanism</td>
<td>Fall 30, Direct blow 2, Insufficiency fracture 2</td>
</tr>
<tr>
<td>Mean (range) time to fracture in months 42.2 (1 to 168)</td>
<td></td>
</tr>
<tr>
<td>Time interval initial procedure to fracture &gt; 3 26, &lt; 3 8</td>
<td></td>
</tr>
<tr>
<td>Stem fixation</td>
<td>Cemented 17, Uncemented 17</td>
</tr>
<tr>
<td>Vancouver fracture type B1 29, C5 5</td>
<td></td>
</tr>
<tr>
<td>Configuration</td>
<td>Oblique 14, Transverse 12, Spiral 8</td>
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* THR, total hip replacement

Table III. Details of the pre- and post-operative University of California, Los Angeles (UCLA) hip scores

<table>
<thead>
<tr>
<th>Mean UCLA hip score (points)</th>
<th>Pre-operative</th>
<th>Post-operative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pain</td>
<td>8.3</td>
<td>8.4</td>
</tr>
<tr>
<td>Activity</td>
<td>4.5</td>
<td>4.0</td>
</tr>
<tr>
<td>Mobility</td>
<td>5.8</td>
<td>5.0</td>
</tr>
<tr>
<td>Function</td>
<td>6.1</td>
<td>5.1</td>
</tr>
<tr>
<td>Total (maximum 40)</td>
<td>24.7</td>
<td>22.5</td>
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Four patients died leaving 30 available for review. Of the 30 fractures, 29 (96.7%) united at a mean interval of 6.4 months (3 to 30). One type-B1 construct failed and was excluded, and another type-B1 fracture had a painfree delayed union which eventually united at 30 months without further surgical intervention. Two fractures united uneventfully with 7° and 9° of varus and one with 6° of valgus alignment of the proximal fragment. No implant had to be revised for loosening and none was radiologically loose at the final follow-up. There were no failures of screws and no radiological cracks in the cement mantle.

Functional outcome. There was no significant difference (p > 0.05) between the pre- and post-operative UCLA hip scores. The total mean score was 24.7 and 22.5 points, respectively (maximum 40) (Table III). A total of 15 patients (52%) were free from pain and 14 (48%) had slight discomfort at the final follow-up. The post-operative mobility status declined in 13 patients (45%) post-operatively.

Complications and re-interventions. Nine major complications (26.5%) occurred in eight of the 34 patients. Of these, four were severely cardiovascular compromised patients who died within one month of surgery. In three patients deep infection was noted (8.8%) which was treated successfully by surgical debridement and with intravenous antibiotics. In one case of infection in a type-C fracture the plate had to be removed after the fracture had healed and a Girdlestone operation performed because of persistent infection. One type-B1 reconstruction failed after four months because of plate failure due to insufficient proximal fixation. This patient was treated successfully by a modular
revision stem (ZMR; Zimmer). Another 89-year-old patient with severe osteopenia who had a Dall-Miles plate for a type-C fracture sustained an insufficiency fracture at the most distal screw five weeks post-operatively. This was treated successfully by a 90° fixed-angle hook plate (Synthes, Brussels, Belgium) and an additional Dall-Miles plate.

Discussion

The incidence of periprosthetic fractures is rising. An analysis of 1049 periprosthetic fractures from Sweden showed that the annual incidence was 0.07% for the first 18 years after primary THR. The accumulated incidence was 0.4% for primary THR and 2.1% for revision THR. Vancouver type-B fractures represented approximately 80% of all fractures which was comparable with the 76% in our series.

The Vancouver classification is most useful, but refinements in the surgical algorithm are required, especially for fractures around a well-fixed femoral component. Two treatment options can be employed using cortical strut allografts with or without plate fixation, or plate fixation alone. Cortical strut allografts have several disadvantages such as cost, availability, transmission of disease, weakening and soft-tissue stripping, with a loss of endosteal healing potential. The development of locking plates and the refinements of surgical technique have changed the armamentarium of the surgeon dealing with these complex fractures. Therefore the interplay between the characteristics of the fracture and the biomechanical features of the different options for treatment should be investigated further, refined and implemented in the treatment algorithm in order to define the most appropriate and cost-effective option in individual situations. The clinical experience obtained in our study adds beneficial arguments for the algorithm since earlier reports have presented failure rates of up to 43% with plate-and-cable system constructs. We believe that there are three important steps in the treatment plan: accurate confirmation of the stability of the femoral component; accurate assessment of the pattern of the fracture with a special emphasis on the integrity of the medial cortex; and technically correct fixation of the construct used based upon its features, with minimal damage to the soft-tissue envelope.

Stability of the femoral component. The pre-operative assessment of type-B1 fractures remains a concern. Brady et al found that the Vancouver classification was valid for type-B2 and type-B3 fractures. However, the validity for type-B1 fractures remained uncertain since they did not assess the stability of the stem in this subgroup at the time of surgery. In a study of 321 fractures, the surgeon’s classification of type-B1 fractures (based upon the pre-operative radiograph and the operation note) was in agreement with the radiologist’s classification in only 34% of the cases. Based upon a large survey of 1049 fractures, Lindahl et al suggested that inadequate pre-operative assessment could have been the reason for the significantly higher failure rates of ORIF for type-B1 fractures in comparison with revision of the stem in type-B2 fractures. They concluded that surgical exploration of the joint and assessment of stability of the femoral component should be recommended for all type-B1 fractures. This has been the policy in our department since 1996, leading to the detection of nine unstable femoral components in 45 fractures (20%). We believe that this approach substantially contributed to the low failure rates of the plate-and-cable constructs in our series. By contrast, the pre-operative assessment was correct in 80% of the fractures and a surgical dislocation could have been avoided. This extra soft-tissue damage might have been an important factor contributing to the high complication rate. For this reason we believe that every effort should be made pre-operatively to ascertain that the femoral component is stable. The assessment should include a detailed history with a high index of suspicion for loosening of the component, pre-fracture radiography, the assessment of ongoing pain before the fracture and the absence of a clear traumatic event. Adequate pre-operative AP and lateral radiographs should be available and, if not, fluoroscopy should be performed before preparation and draping. If there is any doubt, the joint should be dislocated and the stability of the femoral component tested. Another option would be to use pre-operative CT, but to date no validation has been reported. Further research is required to assess stability of the femoral component accurately in presumed type-B1 fractures.

Fracture features. Long oblique or spiral fractures are the most stable and can be fixed by cables with cortical strut grafts. Plates offer the advantage of providing rotational stability by screws fixed on either side of the fracture. Most biomechanical studies have used transverse or short oblique fractures because they are rotationally unstable and tend to unite slowly. Based on these biomechanical studies, and supported by favourable clinical results, biplanar fixation by plates and cortical strut allografts has become the contemporary treatment of choice. However, the question remains as to whether biplanar constructs are always required and how the indications of their use could be refined. Clinically, we used the lack of restoration of the medial femoral cortex as the indication for biplanar fixation. Of the 30 fractures treated without biplanar fixation, 29 healed uneventfully, which compared favourably with the result for strut allografting. Recently, our strategy was supported by a biomechanical study which showed that in the case of a medial cortical bone gap, biplanar constructs had the best multi-directional stiffness. Single-plate constructs were found not to have a significantly different axial load to failure than biplanar constructs. Several plate constructs can be used and have been described with variable rates of success. Each system has its own advantages and disadvantages. Locking-plate systems allow for decreased soft-tissue stripping, require less plate contouring and provide enhanced stability in osteoporotic bone.
high failure rates. Fractures through the proximal screw holes have occurred during torsional loads and early failures of unicortical locked screws with cyclical loading have also been observed. The stiffness of locking plates was lower than that of a plate-and-cable system or biplanar constructs if the integrity of the medial cortex was distorted. However, with a restored medial cortex, the stiffness and axial load to failure was no different from that of the plate-and-cable construct. It thus appears that if the medial cortex can be restored, the use of locking plates applied with indirect reduction techniques may be better than a plate-and-cable construct. Ricci et al. reported good results with various large-fragment plates applied by an indirect reduction technique in 34 type-B1 fractures. We did not use this technique in our study, which might explain the higher infection rate (8.8% vs 7.0%) and the longer time to union in our series (6.4 vs 3.0 months). Another important feature is the effect of the length of fixation on the stability of the construct. The fixation of the proximal fragment is the weakest link in plate constructs, and the bending and torsional forces may become dissipated by a proximal extension of the plate. In agreement with Ricci et al., we used long-plate constructs which extended far proximally and were fixed by one or two trochanteric screws. Ricci et al. advised that the plate should be extended beyond the region of the implant by at least six to eight holes. Further biomechanical research on this subject is required. In addition, any varus alignment of the fracture fragments should be avoided in order to minimise the adduction-bending moments on the construct. Despite the use of intraoperative fluoroscopic images, we had two varus malaligned proximal fragments which fortunately healed uneventfully.

Our results show that a plate-and-cable system has its place within the armamentarium to treat periprosthetic fractures around a well-fixed femoral component, as long as certain prerequisites are met. Soft-tissue stripping is more extensive when cables are used, which is an important disadvantage of a plate-and-cable system, although we have found the modularity of screws and fixed cables to be most useful. Slotted cables can be very helpful when revising a failed plate construct because screw purchase in the damaged proximal fragment is not as cumbersome as when a plate-and-cable system is used. Rotational stability can be provided by trochanteric screws or by unicortical screws around the stem. The debate remains as to whether compromising the cement mantle with bicortical screws would lead to early loosening of the femoral component or that it would produce adverse stress raisers around the screws, leading to stress shielding underneath the plate. However, we are not aware of any clinically adverse effects associated with bicortical screw fixation in these often elderly patients. In younger patients we avoid the use of screws around the femoral component by extending the plate to the trochanteric region. No screw failures or radiological cement mantle cracks were encountered in our series. In osteoporotic patients, the cement mantle could be used in order to gain good purchase of the screws.

Our study does have some important shortcomings. First, the patients were elderly and we did not focus on long-term results. Most of these fractures do occur in elderly patients with a high comorbidity level. The perioperative mortality rate was 12%, which was comparable with that of other reports. Secondly, our fracture fixation technique was not subject to experimental control. Distally, all fractures were fixed by bicortical screws, but the method of fixation in the proximal fragment was variable. It is hard to fix all fractures similarly in these complex cases since each has a unique configuration. Thirdly, we did not compare different fixation constructs. Fourthly, the reduction technique (direct vs indirect) was not subject to experimental control and lastly varus alignment of the femoral component has been reported as a risk factor for failure of ORIF. We did not implement this risk factor in our treatment strategy because most of the patients were referred and we did not have the pre-fracture radiographs of all patients at the time of treatment. Moreover, we postulated that an adequate fracture reduction was more important than the position of the femoral component in the proximal fragment. Uniplanar fixation of periprosthetic fractures around a well-fixed component has been associated with high failure rates. Based on the presented results, we conclude that these fractures can be treated with single plate and cable systems as long as the femoral component has been proven to be well fixed to the bone and certain requirements such as medial cortex restoration and sufficient plate and fixation length, are also fulfilled. Indirect reduction techniques might lead to shorter fracture healing times and fewer complications.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

References


