The bridging nail in periprosthetic fractures of the hip. Incidence, biomechanics, histology and clinical outcomes
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CHAPTER 2

Periprosthetic fractures; an overview of the literature

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Introduction

Total hip arthroplasty (THA) is among the most successful large operative procedures. The prevalence is rapidly increasing due to its success. Firstly, the improved survival rates have led to the fact that the procedure is performed in younger patients more frequently. Secondly, the procedure is offered to an increasing number of patients, who were previously rejected because of old age and co-morbidity.

However, with the increasing numbers of protheses, a higher incidence of complications is observed. Although the number of serious complications is low, a serious complication is a periprosthetic fracture (PPF). Today, periprosthetic fractures are a standard problem that medium to high volume reconstructive orthopaedic clinics have to deal with regularly. PPF can vary from fractures without dislocation, with minimal or no effect on the outcome, to being catastrophic and possibly creating a non-reconstructable problem with an immense effect on the patient’s function.

Often these fractures occur in older, compromised patients, raising mortality rates. Both the increasing number of patients treated with THA, as well as people getting older, create a large population “at risk”. In the literature this increasing incidence of PPF has been reported by a number of study groups.

Incidence

The incidence and magnitude of the problem of periprosthetic fractures is not very clear. Wide ranges of data have been reported the passed years in a number of publications. (Table 1) The amount of periprosthetic fractures is expected to increase next years. An increasing number of total hip arthroplasties are performed each year and people live longer in developed countries due to a higher living standard. Some authors show an increase of the incidence of PPF during consecutive years. The most reliable data come from both the Scandinavian register and the Mayo clinic register. The National Hip Register is a well organised database in Sweden. Finland with a comparable comprehensive registration system enabled Sarvanlinna et al.

<table>
<thead>
<tr>
<th>Author</th>
<th>Year of report</th>
<th>Sample size</th>
<th>Incidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fredin⁹</td>
<td>1987</td>
<td>1,961</td>
<td>0.56%</td>
</tr>
<tr>
<td>Lewallen¹⁰</td>
<td>1998</td>
<td>17,579</td>
<td>0.6%</td>
</tr>
<tr>
<td>Berry⁶</td>
<td>1999</td>
<td>20,859</td>
<td>0.3%</td>
</tr>
<tr>
<td>Lindahl⁸</td>
<td>2006</td>
<td>242,393</td>
<td>0.4%†</td>
</tr>
</tbody>
</table>
to show an increase in incidence during several consecutive years. Other reports rely on clinical registrations related to numbers of implant surgical procedures in one or more hospitals. Those data are regularly retrieved from internal hospital registration.

While some authors describe post-operative fractures, others document intra-operative fractures. Post-operative fractures are often caused by (minor) trauma and intra-operative fractures are regularly reported in uncemented stem placement or revision procedures. Intra-operative fractures are outside the scope of this thesis and therefore only hardly mentioned.

**Risk Factors**

*(Late) postoperative fractures*

Several authors report risk factors based on their analysed series as well as literature. Trauma is a risk factor, as minor trauma accounted for 75% of the periprosthetic fractures (fall at height of sitting or standing). Fall at home was a common mechanism causing periprosthetic fractures (66%). Finally, 8% of the fractures occurs spontaneously. Remarkable is that high energy trauma is rarely the cause of a PPF.

Age has been often mentioned as a risk factor. However due to alterations in bone stock, muscle strength and balance this risk is likely to be multifactorial. The age at initial arthroplasty is intensively evaluated by several authors. Age less than seventy years old at primary surgery has been documented as a risk factor. Higher activity may play a role in these patients or more extensive remodeling of the femur.

Most reports did not establish gender as a risk factor. However, gender is probably a multi-factorial risk as well since it is closely associated with osteoporosis. Despite the few reports critically evaluating osteoporosis as a risk factor it is commonly accepted and reported. The contribution of low energy falls to the development of PPF and the co-existence of vertebral and previous metaphyseal fractures in the PPF patient group support the hypothesis. Several primary indications for hip arthroplasty are reported as risk factors. Rheumatoid arthritis and hip fracture prior to the primary implant were derived as risk factors from Scandinavian registries. The most common cause of PPF is osteolysis due to particle disease and a well established risk factor according to the literature. In combination with loosening of the implant an unstable situation exists leading to increased fracture risk. Jensen and Fredin found evidence of loosening prior to fracture in 50% of their cases. Patients with revision implants often are more likely to suffer from a periprosthetic fracture than do patients with a primary total hip arthroplasty. The interval from the index surgery to fracture is shorter in patients with revision implants. Lindahl et al. showed a mean implant survival of 7.4 years in primary arthroplasties and 3.9 years after one revision. This is in concordance with a series of our own, showing a mean
of 7.8 years and 3.9 years of implant survival, respectively. (Chapter 5 of this thesis) Stem design is much debated focused on wedged versus anatomical design in uncemented THA. A tapered stem is expected to increase stress in the proximal femur by some authors.\(^{16}\) Furthermore alterations to the femoral integrity are known risk factors. Screw holes and cortical perforations or previous osteotomies can have significant effect on the mechanical properties of the bone and may lead to a fracture. However, the reports clarifying the influence of these factors on PPF are lacking.

**Classification**

In the treatment of periprosthetic fractures both the patient and the type of fracture must be taken into account, often leading to individualised treatment methods. Several authors propose uniform treatment strategies while others consider the whole patient in the decision making. The first step leading to treatment decisions is to categorise conditions in a classification. For PPF several classifications have been described.\(^{2,17-26}\) The earliest report is by Parrish and Jones in 1964 describing the anatomical location of the fracture (Table 2).\(^{27}\)

<table>
<thead>
<tr>
<th>Group</th>
<th>Site of fracture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td>Fractures in trochanteric area</td>
</tr>
<tr>
<td>Group 2</td>
<td>Fractures in the proximal part of the shaft</td>
</tr>
<tr>
<td>Group 3</td>
<td>Fractures in the mid-shaft</td>
</tr>
<tr>
<td>Group 4</td>
<td>Fractures in the distal part of the shaft of the femur</td>
</tr>
</tbody>
</table>

After their report numerous classifications were published all based on location of the fracture. Many of these classifications are descriptive and only provide information on the site of the fracture, whereas they provide no added value to the type of preferred treatment.\(^{17,20}\) In 1995 Duncan and Masri incorporated quality of bone stock as well as loosening of the implant in the Vancouver classification.\(^{19,20}\) (Table 3) This enabled others to work out treatment strategies based on fracture classifications.\(^{2}\)

More recently Ninan et al.\(^{28}\) introduced the more simplified Coventry classification, while taking loosening of the implant into account. They divide the fractures in two groups. Those with “unhappy hips” with signs of loosening and “happy hips” with well fixed implants. The first group should undergo revision arthroplasty, the latter might benefit from internal fixation. Currently the most widely used classification is the Vancouver classification.
Chapter 2

Fixation methods

In accordance to the development of materials for internal fixation in normal femora, the evolution of fixation devices has a long history. The first report 1964 by Parrish et al.\textsuperscript{27} made use of intramedullary Rush rods bypassing the fracture. Additionally wire loops and screws were used. After this report many different fixation methods were described.

Straps

The Parham’s straps were developed in 1913 for fracture fixation and found their use in PPF treatment as well.\textsuperscript{17} A steel ring was tightened with a bolt around the fracture fragments. Major drawback was the damage to the blood supply of the femur. This led to abandoning of this concept. Partridge nylon straps were developed in the seventies for circular fixation of the femur, having the same negative effects on bone. Moreover the biomechanical effects limited the use of these cables. Only few reports document results of the Partridge system.\textsuperscript{29-31} De Ridder and colleagues concluded in a single prospective large series that the indication for the use of this simple osteosynthesis method is swift convalescence by splinting the periprosthetic femoral fractures.\textsuperscript{32} Supplemental use of Partridge straps is documented in a number of case reports.\textsuperscript{33,34} More recent publications indicate that cerclage techniques lack sufficient stability when applied without additional types of osteosynthesis.\textsuperscript{35}

Cable – Plate

The capacity of cables to provide circular grip on fracture fragments lead to the combined use of plates and cables. The Ogden plate is an example of this development. It consists of Parham straps and stainless steel wires and screws. Good clinical results were obtained in over 80%.\textsuperscript{36} However, finite element analysis showed high stress areas around the end of the plate and the need for additional wiring.\textsuperscript{37} Rotational analysis was not performed. Therefore no strict conclusive rules could be given concerning superiority of the implant and the post-operative management.

Dall-Miles plate cable construction offers a combination of plating, cable

<table>
<thead>
<tr>
<th>Type</th>
<th>Site and characteristics of fracture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type A\textsubscript{g}</td>
<td>Fractures of greater trochanter</td>
</tr>
<tr>
<td>Type A\textsubscript{p}</td>
<td>Fractures of lesser trochanter</td>
</tr>
<tr>
<td>Type B\textsubscript{1}</td>
<td>Fracture around the stem or extending just below it in which the femoral component is solidly fixed</td>
</tr>
<tr>
<td>Type B\textsubscript{2}</td>
<td>Fracture around the stem or extending just below it in which the femoral component is loose</td>
</tr>
<tr>
<td>Type B\textsubscript{3}</td>
<td>Fracture around the stem or extending just below it in which the femoral component is loose and there is severe bone stock loss</td>
</tr>
<tr>
<td>Type C</td>
<td>Fractures well below the tip of the stem</td>
</tr>
</tbody>
</table>

Table 3. Vancouver classification \textsuperscript{19}
grip and screw fixation in multiple directions. This provides evasion of the stem while inserting the screws. Reports with good results are published, however in most reports implants were used (e.g. long stems, allograft struts). The use of Dall-Miles as solitary implant delivers a failure rate of 43%. This is explained by the unfavourable rotational stability. Fixation with cables alone should therefore be avoided.

**Plating**

Plate osteosynthesis has evolved as well. The first reports concerned compression plating. Violation of the cement mantle and direction of the screws, as well as stress rising, were concerns for the authors. Tsiridis et al. advised to use a combination of DCP-plates and allograft struts for stable Vancouver B1 fractures. In unstable implants a long stem revision was advised in combination with a plate. Ricci et al. published a series of 37 patients with a Vancouver B1 fracture treated with plating alone, while preserving soft tissue sleeves around the femur. An indirect reduction was performed under fluoroscopy and fixated with uni- or bi-cortical screws. All fractures united at 3 months with minimal complications. This emphasises the importance of preservation of the biological environment.

Locking plates are a relatively new treatment modality. The advantages of these implants outweigh the difficulties of indirect fracture reduction and fracture bridging capacities of the plates. Berlusconi et al. concluded after evaluation of their series that LCP is the gold-standard in the treatment of Vancouver B1 fractures. Only a small series of 12 patients has been documented in literature having a comparable failure rate to conventional plating (16%). Median time to union was 4.8 months (4-7 months). Buttaro et al. concluded that locking plates offer no advantages as the complication rate is similar to the conventional plating technique. Future patients might benefit from carbon fibre plates, described by Baker et al. The mechanical properties of these plates could be beneficial. More research should be performed as in their series periprosthetic fractures far distal to the stem were evaluated.

A separate form of treatment with a plate is the Mennen plate, introduced in 1979. The device consists of a clamping plate grabbing the longitudinal femur. Early reports showed good-excellent results. However, the following publications demonstrated inferior results. The a-traumatic theory of the application of the plate was disputed regarding the number of non-unions and failures. A large retrospective study from The Netherlands by Noorda and Wuisman recorded healing rates of 72% with extensive non-weight bearing periods and plate failure in 23%. They concluded against the Mennen concept, specifically for unstable fractures.

**Intramedullary fixation**

Intramedullary implants have been used since the first report of periprosthetic fractures in 1964. Bypassing the fracture with intramedullary rods provided stability. Other early publications describe Ender nails and lengthened
implants.\textsuperscript{47,48} The latter technique demands initial removal of the stem. The intramedullary concept was limited by medullar cavities filled with cement. Cement removal can be done by various techniques. More recently Zuurmond et al.\textsuperscript{49} reported the use of retrograde Bridging nailing in compromised geriatric patients, eliminating stress zones and providing stability. The clear advantage is preservation of surrounding tissue of the femur, thus preserving bone biology and direct post operative weight-bearing. The use of supracondylar retrograde nails leaves a stress riser between the implants. Coupling of the implants with a Bridging nail system eliminates this problem.

**Revision stem**

Many authors favor the use of a long stem revision arthroplasty in cases with loosening of the stem. Long stems bypass the fracture and provide immediate stability combined enabling direct postoperative mobilisation. The stem should bypass the fracture with at least 2 times the cortical diameter.\textsuperscript{50} In Vancouver B2 type fractures a long stem is the treatment of choice. Springer et al.\textsuperscript{51} preferred the use of fully coated implants. Treatment of Vancouver B3 fractures is most challenging. In cases with severe additional cortical bone loss, allograft struts are preferably used.\textsuperscript{51-53} Especially in younger patients the emphasis is on restoration of bone stock. Proximal femoral replacement is a salvage option, although the reported complication rates are high.\textsuperscript{54} Long term risks of revision arthroplasty are stem breakage, loosening and instability due to poor muscle forces and capsular insufficiencies.

**Biomechanics**

Mechanical comparison of all these concepts generally showed superiority when a combination of techniques was used. Cerclages tested alone are mechanically inferior to a combination of a plate and cable. Schmotzer et al.\textsuperscript{55} showed that proximal wiring in Ogden plates is inferior to screw fixation. Long stem revisions in some type of fractures should be accompanied by allograft struts. However, the effect of osseous integration could not be established. The effect of more than one fixation device (2 plating technique or plate and allograft) demands more soft tissue stripping and therefore biological impairment. The locking compression plate (LCP) concept shows less favourable mechanical aspects, but the authors emphasise the biological advantages.\textsuperscript{56}

**Treatment strategies**

Optimal treatment for periprosthetic fractures remains a subject of discussion in the literature. The first treatment strategies were developed by Parrish et al.\textsuperscript{27} based on their own series. In 1981 Bethea et al.\textsuperscript{17} advised conservative treatment in spiral fractures around the stem and for distal fractures below the stem. Johansson et al.\textsuperscript{20} published treatment proposals and mentioned long stem revision when the fracture stretched from stem-level to distal of the
stem. However fractures proximal of the tip of the stem could be treated conservative when the stem has a stable fixation. A large analysis of PPF was done by Mont and Maar.\textsuperscript{24} Their data were retrieved from many small number sub-series (critical appraisal). Although they gathered a large number of patients their outcomes were difficult to interpret. In their plan of treatment cerclages and revision were enclosed as well as conservative treatment for fractures distal of the stem. For supracondylar fractures no advice was given. Currently most treatment algorithms are based on the Vancouver classification. In 2002 Haddad et al.\textsuperscript{52} described results for the Vancouver B1 fractures. Cortical strut grafts offered both mechanical and biological advantages. The most challenging fractures are the Vancouver B3 fractures with poor bone stock and loose prosthesis. Parvizi et al.\textsuperscript{2} analysed a series of type B fractures and proposed a treatment algorithm. In case of a loose prosthesis the algorithm always ends with large hip replacement surgery. Recently Ninan et al.\textsuperscript{28} proposed a decision scheme base on their treated patients. They simplified the problem, introducing the term “unhappy hip”. These patients had a hip prosthesis with established loosening prior to fracture, worsening hip pain, fracture with minimal trauma or radiologic signs of loosening. They are preferably treated with a form of revision arthroplasty. Patients without loosening or without minor trauma were supposed to have a “happy hip” and could be treated with osteosynthesis unless the fracture pattern caused acute instability of the stem.

**Morbidity and complications**

Periprosthetic fracture treatment is associated with high numbers of complications and mortality.\textsuperscript{8,13,44,57} Reasons are high age, co-morbidity, poor bone stock and unfavorable local biological factors. The patient group is often compared to proximal femoral fracture patients with similar high mortality. Recently Bhattacharyya et al.\textsuperscript{58} did a sex-matched control study comparing the periprosthetic fracture patients with hip fracture patients. Their reported mortality was 11\% (12/106). They found a mortality rate similar to treated hip fracture patients. Furthermore they concluded that patients treated with internal fixation in Vancouver type B fractures had a higher mortality than patients treated with revision arthroplasty. Selection bias may have occurred as frail geriatric patients are not selected for long stem revision arthroplasty procedures. They advise revision in doubtful cases. Importantly they found an increased mortality at one year in patients with a delay of more than two days before surgery. Lindahl et al. reported higher mortality rates after surgery for periprosthetic fractures especially for patients younger than 70 years.\textsuperscript{8,13} Underlying disease and co-morbidity were named as possible explanations for this remarkable finding. The estimated probability of death from PPF at the age of 70 was 2.1\% for men and 1.2\% for women. In a study from Edinburgh, McLaughlan et al.\textsuperscript{57} demonstrated a mortality rate of 20\%. This rate was derived from a retrospective analysis of 45 fracture patients with 9 deceased patients.
within 14 weeks. Another five patients remained untraced. They report that 2 patients died of a cardiac event due to cement insertion during surgery. The co-morbidity of the patients was regarded as the main cause of the other postoperative deaths. Several studies report their results regarding an operative policy including complications and deaths. An overview is given in Table 4. The study of Ninan et al.\textsuperscript{28} describing a treatment strategy had a mortality of 13\% (7/53). The re-operation rate was 19\% (10/53). The latter clarified by refractures and infections. Parvizi et al.\textsuperscript{2} did not report the length of follow up. One direct postoperative death was encountered in his series of 123 PPF patients. A total of 22 complications were reported (18\%) including seven failures of the construction were reported (6\%). There is a wide range of mortality numbers given by the different authors. In general larger series show worse numbers.

<table>
<thead>
<tr>
<th>Study</th>
<th>Year</th>
<th>Number of patients</th>
<th>Confirmed Reoperations</th>
<th>Reported complications</th>
<th>Mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooke\textsuperscript{59}</td>
<td>1988</td>
<td>37</td>
<td>12 (32%)</td>
<td>n/r</td>
<td>0</td>
</tr>
<tr>
<td>McLaughlan\textsuperscript{57}</td>
<td>1997</td>
<td>45</td>
<td>3 (7%)</td>
<td>5 (11%)</td>
<td>9 (20%)</td>
</tr>
<tr>
<td>Tsiridis\textsuperscript{60}</td>
<td>2002</td>
<td>16</td>
<td>4 (25%)</td>
<td>2 (13%)</td>
<td>1 (6%)</td>
</tr>
<tr>
<td>Parvizi\textsuperscript{2}</td>
<td>2004</td>
<td>123</td>
<td>7 (6%)</td>
<td>22 (18%)</td>
<td>1 (1%)</td>
</tr>
<tr>
<td>Klein\textsuperscript{61}</td>
<td>2005</td>
<td>21</td>
<td>4 (19%)</td>
<td>6 (29%)</td>
<td>3 (14%)</td>
</tr>
<tr>
<td>Lindahl\textsuperscript{62}</td>
<td>2006</td>
<td>1045</td>
<td>109 (10%)</td>
<td>n/r</td>
<td>n/r</td>
</tr>
<tr>
<td>Kaab\textsuperscript{63}</td>
<td>2006</td>
<td>13</td>
<td>1 (8%)</td>
<td>3 (23%)</td>
<td>0</td>
</tr>
<tr>
<td>Lindahl\textsuperscript{8}</td>
<td>2006</td>
<td>321</td>
<td>54 (17%)</td>
<td>45 (14%)</td>
<td>42 (34%)</td>
</tr>
<tr>
<td>Buttaro\textsuperscript{44}</td>
<td>2007</td>
<td>14</td>
<td>4 (30%)</td>
<td>7 (50%)</td>
<td>0</td>
</tr>
<tr>
<td>Ninan\textsuperscript{28}</td>
<td>2007</td>
<td>53</td>
<td>10 (19%)</td>
<td>n/r</td>
<td>7 (13%)</td>
</tr>
<tr>
<td>Bhattacharyya\textsuperscript{58}</td>
<td>2007</td>
<td>106</td>
<td>n/r</td>
<td>n/r</td>
<td>12 (11%)</td>
</tr>
</tbody>
</table>

Overview of reported reoperations and complications
n/r = not reported

Several authors have tried to evaluate risk-factors for development of complications after periprosthetic fractures. A risk factor defined by Lindahl was plate osteosynthesis for a Vancouver B1 fracture.\textsuperscript{13}

**Discussion**

When discussing the problem of periprosthetic fractures, the emphasis is more on the difficulty of treatment than on the increasing incidence. The incidence is expected to increase due to ageing and increasing numbers of total hip arthroplasties performed. The number of THA performed in The Netherlands almost doubled since 1992, resulting in approximately 25,000 procedures in 2006. The incidence of PPF is reported between 1\% and 6\%.\textsuperscript{4,6,9,10,19} Uncemented stems show higher numbers, especially when
combined with intra-operative fractures. Operative technique and bone quality may play an important role in the aetiology.

The access to an implant registry facilitates the study of long term complications. Great examples are the Swedish Hip Register and the Norwegian Register. When a separate code for periprosthetic femoral fractures is defined, exact numbers can be reported. The inclusion of fracture classification system for PPF is preferable for research purposes. The Vancouver classification is most widely used and easy to apply. Other classification methods could be more precise on some points, but are less reliable when it comes to inter-observer variability. Classifications with the purpose to establish a treatment protocol have been reported. Some authors tend to advise revision in all cases of loosening to prevent adverse effects and implant stability problems. However, no reports critically mention the impact of a revision arthroplasty on older patients. Asymptomatic loosening of hip stems in institutionalised patients are not undoubtedly feasible indications for revision. When a periprosthetic fracture occurs, the general health aspects of these patients should be addressed and enclosed in the treatment algorithm.

During the past years several methods of fracture fixation found their use in periprosthetic fracture treatment. The emphasis is on revision arthroplasty in fractures with a loose stem. For stable implants numerous forms of internal fixation are at the disposal of the treating surgeon. Cerclage systems should be accompanied by other forms of fixation in order to diminish complications. Plate fixation is associated with mechanical complications as well, especially in type B1 fractures. Bone biology is an important aspect in fracture healing. Recent developments in plate osteosynthesis, including indirect fracture reduction and less invasive procedures, tend to respect surrounding tissue. This may be beneficial to fracture healing, although callous formation is generally delayed after plate osteosynthesis of the femur. Unfortunately, early load bearing and ambulation are not frequently feasible when these techniques are performed.

The importance of early mobilisation lies in the prevention of general complications. To reduce the rate of complications and to optimise the treatment for periprosthetic fractures more research is needed. This research should focus on the holistic outcome for the patient in favour of studies of one specific (new) implant. Regarding the low incidence, this is preferably performed in a multi-centre trial in a prospective way. Patient based outcome scores for quality of life and activities of daily life should certainly be included in this registration to complete the picture.
Chapter 2

Reference List


55. **Schmotzer H, Tchejayan GH, Dall DM.** Surgical management of intra- and postoperative fractures of the femur about the tip of the stem in total hip arthroplasty. *J Arthroplasty* 1996;11:709-17.


