Stem Fracture of the Cementless Spongy Metal Lübeck Hip Prosthesis

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Abstract: We performed 204 cementless total hip arthroplasties using a fully porous stem made of a cast cobalt-chrome-molybdenum alloy. Five stems fractured at the middle part. Champagne-fluted canals (P<.0001) and low canal fillings 1 cm below the lesser trochanter (P = .02) significantly correlated with stem fractures. Subsequent surgery revealed that all of the proximal parts were surrounded by fibrous tissue, and the distal parts showed bone ingrowth. Numerous voids were present close to the surface of the implant body. The core diameters of the fractured stems were 4 to 5 mm. The fractures may be attributed to the combination of the lack of proximal support, a champagne-fluted canal, the fully porous stem made of a cast cobalt-chrome-molybdenum alloy, and the narrow dimension of the stem core. Key words: stem fracture, cementless total hip arthroplasty (THA), cast cobalt-chrome-molybdenum alloy, champagne-fluted canal, lack of proximal support.

Fracture of the femoral component has been reported sporadically as a complication after total hip arthroplasty (THA). Most fractures occurred in cemented prostheses [1–10]. Fewer stem fractures were reported after cementless THA than cemented THA. Stem fractures after cementless THA were attributed to the weak junction of the madreporic corrugations and the smooth plate [11], cracking from the beaded configuration, the smelting technology, overstrain before mechanical primary stabilization [12], the depth of the recess for the titanium mesh [13], and the corrosive attack in the prosthetic neck [14–16]. Few reports detail the risk factors of stem fractures after cementless THA, however. We identified 5 cases of fractures of a cementless and fully porous stem made of a cast cobalt-chrome-molybdenum alloy and studied the clinical presentations, radiographs, histologic examinations, and bone scans to analyze the risks of failure.

Materials and Methods

Between May 1987 and June 1995, we performed cementless primary THA, using a spongy metal Lübeck hip prosthesis (S & G, Lübeck, Germany) [17,18], on 204 hips of 176 patients. This system is not approved by the U.S. Food and Drug Administration (FDA) for implantation in the United States. There were no selective criteria for the patients for this system. In the Lübeck system, the acetabular and femoral components are made of a cast cobalt-chrome-molybdenum alloy, and the entire surface has a structure similar to that of cancellous bone. This spongy metal surface with a...
pore size ranging from 800 to 1,500 μm was produced as an integral part of the components. Five sizes of stem are available: 9-, 10-, 11-, 12-, and 13-cm lengths. The same surgical team did all of the operations under sterile conditions. A posterolateral approach to the hip was used in all patients, who were under general anesthesia. No intraoperative fractures occurred. The average patient age was 51.2 years (range, 24 to 77 years), height was 154 cm (range, 142 to 178 cm), and weight was 55 kg (range, 38 to 100 kg).

Five femoral components fractured (2.5%). The clinical and operative details of these cases and years from insertion to fracture are shown in Table 1. The fracture rate is 12.5% of the 9-cm stem, 1.5% of the 10-cm stem, and 0% of the 11-cm through 13-cm stems. One patient had bilateral stem fractures (Cases 1 and 2). In 3 cases (Cases 1, 2, and 5), patients underwent revision THA. In the other 2 cases (Cases 3 and 4), the patients were kept under close observation because they did not feel severe pain during daily activities. All patients undergoing THA were evaluated clinically with the Merle d’Aubigne and Postel hip scoring system [19] before surgery, 1 year after surgery, and annually thereafter. This system allocates a maximum of 6 points each for comfort level (pain), range of motion (mobility), and ambulatory skill (walking ability), for a maximum total score of 18 for a normal hip. Patients also were asked about their pain.

Anteroposterior radiographs of the hip and lateral radiographs of the proximal femur were taken after surgery at 1 week, 6 months, 1 year, and annually thereafter. To evaluate femoral geometry, the canal flare index was calculated from the anteroposterior view before surgery [20]. The canal filling was measured 1 cm below the lesser trochanter and 1 cm above the stem tip on the anteroposterior radiographs 1 week after surgery. The fixation of the femoral components was assessed radiographically according to Engh, Massin, and Suthers’ criteria [21]. Subsidence of the components, radiolucent lines [22], and osteolysis [23] also were monitored. Femoral component subsidence was defined as a change of >4 mm [24]. In the 3 cases of revision THA, the diameters of the core and fracture surface at the level of the stem fractures were examined. In this system, there was variation of core diameters, even the same size of stem. The core diameter without stem fracture could not be measured. The stem diameters of the middle part of the femoral stem were used to evaluate the stem fractures on the anteroposterior radiographs 1 week after surgery.

Histologic findings were investigated in the following way: Samples were fixed in 10% formalin solution, embedded in polymethyl methacrylate, sectioned transversely, and stained with Stevenel’s blue and van Gieson’s picro-fuchsin. In all 5 patients, technetium-99m medronate scintigraphy was done at the time of the expression of symptoms or when stem fracture was suspected radiologically. Three hours after intravenous injection, anterior and posterior view bone scintigrams of the total body and bilateral hips were obtained.

Merle d’Aubigne and Postel hip scoring, canal filling, and the differences in stem diameters between the patients with stem fracture and the patients without stem fracture were analyzed statistically by the Mann-Whitney U test. Femoral geometry was analyzed by the Fisher exact probability test. A P value < .05 was considered significant.

### Results

No statistically significant differences were found in age (P = .471), height (P = .182), or weight (P = .540) between the patients without stem fractures and the patients with stem fractures (Mann-Whitney U test). In the patients with 9-cm or 10-cm stems, no statistically significant differences were found in age (P = .412), height (P = .057), or

<table>
<thead>
<tr>
<th>Case</th>
<th>Age at THA* (yr)</th>
<th>Sex</th>
<th>Height (cm)</th>
<th>Weight (kg)</th>
<th>Diagnosis</th>
<th>Stem Size (mm)</th>
<th>Years From Insertion to Fracture</th>
<th>Fracture Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>49</td>
<td>F</td>
<td>147</td>
<td>56</td>
<td>Osteoarthritis secondary to DDH</td>
<td>90</td>
<td>9.0</td>
<td>Middle</td>
</tr>
<tr>
<td>2</td>
<td>49</td>
<td>F</td>
<td>147</td>
<td>56</td>
<td>Osteoarthritis secondary to DDH</td>
<td>90</td>
<td>4.7</td>
<td>Middle</td>
</tr>
<tr>
<td>3</td>
<td>52</td>
<td>F</td>
<td>152</td>
<td>59</td>
<td>Osteoarthritis secondary to DDH</td>
<td>90</td>
<td>4.2</td>
<td>Mid-distal</td>
</tr>
<tr>
<td>4</td>
<td>49</td>
<td>F</td>
<td>146</td>
<td>44</td>
<td>Osteoarthritis secondary to DDH</td>
<td>90</td>
<td>4.8</td>
<td>Middle</td>
</tr>
<tr>
<td>5</td>
<td>48</td>
<td>F</td>
<td>168</td>
<td>48</td>
<td>Osteoarthritis secondary to DDH</td>
<td>100</td>
<td>9.5</td>
<td>Mid-distal</td>
</tr>
</tbody>
</table>

Abbreviation: DDH, developmental dislocation of the hip.
weight ($P = .431$) between the patients without stem fractures and the patients with stem fractures (Mann-Whitney $U$ test).

All but 1 patient felt a sudden onset of severe thigh pain; in 1 case (Case 4), the pain gradually decreased. In another case (Case 3), the pain was sometimes mild and did not limit the patient’s daily activity. In 3 cases (Cases 1, 2, and 5), the patients were unable to bear weight on the lower extremity.

Merle d’Aubigne and Postel hip scores were a mean of 7.3 before surgery (range, 6 to 10; pain, 1.8; mobility, 3; walking ability, 2.5) and a mean of 16 at 1 year after surgery (range, 15 to 17; pain, 6; ability, 4.8; walking ability, 5). These scores did not decrease in any patient from 1 year after surgery until the onset of fracture symptoms. In the hips without stem fracture, hip scores were a mean of 8 before surgery (range, 4 to 12; pain, 1.3; mobility, 4; walking ability, 2.7) and a mean of 17 at 1 year after surgery (range, 15 to 18; pain, 5.9; ability, 5.5; walking ability, 5.6). No statistically significant differences were seen in hip scores before surgery ($P = .325$) or at 1 year ($P = .100$) between the patients with stem fracture and the patients without fracture.

Canal flare index and canal filling of the hips with stem fracture are shown in Table 2. All but 1 hip had champagne-fluted canals. In the patients without stem fracture, champagne-fluted canals were recognized in 1.7% of the hips, canal filling measured below the lesser trochanter ranged from 73% to 100% (mean 87.2%), and canal filling measured above the stem tip ranged from 70% to 100% (mean 88.1%). We observed statistically significant differences between the patients with stem fracture and the patients without fracture in the type of femoral geometry ($P < .0001$) and in the canal filling 1 cm below the lesser trochanter ($P = .020$). No statistically significant difference was seen in canal filling above the stem tip ($P = .070$) between the patients with stem fracture and the patients without fracture.

In 1 patient who had a stovepipe canal, the femoral component was undersized in relation to the femoral intramedullary canal (Case 5). Two years after surgery, no stem subsidence was evident. All 5 stems had a radiolucent line <1 mm in width in zone 1 and radiographic appearances suggestive of bone ingrowth in zones 3 and 5.

In 3 cases (Cases 1, 2, and 4), the fractures occurred at the middle part of the femoral stem. Before the stem breakage, cortical hypertrophy was seen in zones 2 and 6. Nine years after THA, Case 1 still showed osteolysis in zone 1. In 2 cases (Cases 3 and 5), the component fractures occurred at the mid-distal stem level. Nine years after THA, Case 5 still showed osteolysis in zone 1 and cortical hypertrophy in zone 6. The other case (Case 3) showed neither osteolysis nor cortical hypertrophy (Fig. 1).

Of the hips without stem fracture, none showed any cortical hypertrophy. In 4 of the 5 cases, varus migration of the stem fragment was progressive after stem fracture. In the fifth case, (Case 3), no progressive migration of the proximal stem fragment was seen in the 5 years before the latest follow-up.

In 3 cases (Cases 1, 2, and 5), the proximal components were removed easily during revision surgery. The distal components were incorporated solidly in the bone, and their removal was extremely difficult without fenestration of the femur. Seen microscopically, the proximal part was sur-

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**Table 2. Canal Flare Index and Canal Filling of Patients With Stem Fracture**

<table>
<thead>
<tr>
<th>Case</th>
<th>Canal Flare Index</th>
<th>1 cm Below the Lesser Trochanter Level (%)</th>
<th>1 cm Above the Stem Tip Level (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5</td>
<td>82.1</td>
<td>100</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>86.7</td>
<td>100</td>
</tr>
<tr>
<td>3</td>
<td>5.5</td>
<td>75</td>
<td>94.4</td>
</tr>
<tr>
<td>4</td>
<td>5.5</td>
<td>81.4</td>
<td>100</td>
</tr>
<tr>
<td>5</td>
<td>2.7</td>
<td>66.7</td>
<td>71</td>
</tr>
</tbody>
</table>

---

**Fig. 1.** In Case 3, the component fractured at the mid-distal stem level 4.2 years after THA. No cortical hypertrophy was seen.
rounded by fibrous tissue, and the distal part showed bone ingrowth with some fibrous infiltration (Fig. 2). Numerous voids were noted close to the surface of the implant body (Fig. 3). The core diameters of the fracture level were 4 mm in Cases 1 and 2 and 5 mm in Case 5.

In the hips with stem fracture, the mean of the stem diameters of the middle part of the stem was 7.4 mm (range, 6 to 8 mm) for the 9-cm stem and 9 mm (range, 8 to 11 mm) for the 10-cm stem. In the hips without stem fracture, the mean of the stem diameters of the middle part of the stem was 8.3 mm (range, 6 to 10 mm) for the 9-cm stem and 9 mm (range, 8 to 11 mm) for the 10-cm stem. In the patients with 9-cm or 10-cm stems, no statistically significant differences were found in stem diameters ($P = .107$).

Anteroposterior bone scintigrams showed increased uptake in the proximal region above the fracture level in 4 hips and none below the fracture level. In 2 of these cases (Cases 1 and 4), increased uptake was apparent when stem fracture was difficult to detect on plain radiography (Fig. 4). In the other 2 cases (Cases 2 and 5), positive findings on bone scintigrams were concomitant with positive findings on plain radiography. In 1 hip without severe pain or cortical hypertrophy (Case 3), the scintigram showed normal uptake.

**Discussion**

The mechanism causing stem fractures varies, with many factors, including the materials used, clinical factors such as the patient’s femoral geometry, and location and direction of the applied loads, playing a part. In this system, the femoral component was made of a cast cobalt-chrome-molybdenum alloy that reportedly may contain pores, voids, and nonmetallic inclusions [25]. In this study, numerous voids were seen close to the surface of the implant body. Any of these defects could cause sufficient decrease in the fatigue resistance of the alloy to produce fractures.

Stem fractures occur when implants lack proximal support from the outset [10,13,25]. Together with rigid distal fixation, the stems fracture via a classic cantilever bending. In the present study, radiographs of all 5 cases and histologic findings suggested that the conditions of lack of rigid support in the proximal area and rigid fixation at the distal end were present.

The rate of champagne-fluted canal type was higher and the rate of canal filling 1 cm below the lesser trochanter was lower in the hips with stem fracture than in the hips without stem fracture. Reportedly the closer an implant is to the endosteal...
cortex, the greater the development of bone ingrowth up to and within the porous surface structure [26]. When the fully porous stem was used for the narrow and champagne-fluted canals, the likelihood of having a proximal undersized stem leading to rigid distal fixation might increase.

The FDA suggested that smaller dimensions and porous coating would lower the fatigue strength [27]. Although no significant differences were observed for stem diameters, the narrower diameters were observed in the fractured stem. The core diameter of the fractured stems at the failure sites was 4 to 5 mm. The narrow diameter of the component might be considered a risk factor [13].

In the present study, fibrous tissue was shown around the stem even at its distal part. In this
system, large pore size was disadvantageous for bone ingrowth, especially in the cancellous bone, and fibrous infiltration was inevitable, resulting in the migration of polyethylene particles. Patients with such a narrow component should be monitored closely because the greater the osteolysis around the proximal part of the stem, the greater the risk of femoral stem fracture [28].

We found that most failures occurred in the middle one third of this stem. Hampton, Andriacchi, and Galante [5] analyzed the forces on cemented femoral stems and found that the load produced maximal tensile stress along the middle one third of the lateral surface of the stem and maximal compressive stress along the medial surface. The load produced maximal tensile stress in the region where stem fractures were observed most frequently [3].

Bone scintigraphy is reportedly useful in diagnosing the cause of pain after THA [29,30]. Of the 5 cases, all but 1 had cortical hypertrophy in zones 2 and 6. The lack of rigid support, micromotion, and migration in the proximal area may have resulted in cortical hypertrophy. Although bone scintigraphy showed an increased uptake in the proximal region above the fracture level in 4 hips, in the fifth hip, plain radiography showed a stem fracture despite negative findings on bone scintigraphy. In this case, migration of the proximal stem fragment was not progressive in the 5 years before the latest follow-up. The negative findings on bone scintigraphy despite stem fracture suggest that the proximal stem fragment may have been stabilized by fibrous tissue, making immediate revision surgery unnecessary to prevent rapid bone loss.

**Conclusion**

Lack of rigid support in the proximal area of the stem, rigid distal stem fixation, a champagne-fluted femoral canal, and a fully porous stem made of a cast cobalt-chrome-molybdenum alloy may be the contributing factors causing stem fractures after cementless THA. Bone scintigraphy may be effective in diagnosing stem fractures earlier and in deciding the timing of revision surgery.

**Acknowledgment**

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**References**

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