

# EPIDEMIOLOGY

## Hip and Knee

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Intraoperative and postoperative periprosthetic fractures appear to be increasing in number.<sup>20,32,56</sup> Intraoperative fractures have become more common with the advent of uncemented press-fit implants.<sup>20</sup> Postoperative fractures have also become more common as the population of at-risk patients with joint arthroplasty has increased.<sup>20</sup> The number of patients living with hip and knee arthroplasties has risen considerably over the last two decades, and after several decades of joint arthroplasty, the number of patients with multiply revised joints, bone loss, and osteolysis has also risen.

This article reviews the epidemiologic features of periprosthetic fractures around total hip arthroplasty and total knee arthroplasty according to the site of fracture occurrence. The frequency and cause of intraoperative and postoperative periprosthetic fractures vary by anatomic site. For each anatomic site, unique risk factors, some demographic and some technical, appear to be related to risk of fracture. For several anatomic sites, excellent articles that collate large numbers of series are available to the reader and provide aggregate information concerning the epidemiology of these fractures.<sup>13,29,31,37,53,56</sup> From a broad perspective, there is little information in the literature on the relative frequency of periprosthetic fractures at each anatomic site. To provide some perspective, this article also

makes use of previously unpublished data from the Mayo Clinic total joint registry.\*

### PERIPROSTHETIC FRACTURES AROUND TOTAL HIP ARTHROPLASTY

#### Periprosthetic Acetabular Fractures

##### *Intraoperative*

Intraoperative periprosthetic acetabular fractures are a phenomenon ascribable to use of press-fit uncemented acetabular components. The fractures vary in severity from minor cracks involving only the rim of the socket to

\*Data from the Mayo Clinic joint registry are used in this article to provide figures on the relative frequency of different types of fractures (see Tables 1 and 2). The data do not provide absolute prevalence information because they represent all hip and knee arthroplasties done at the Mayo Clinic to date, some performed recently and some performed more than two decades ago. Furthermore, the data represent minimal figures because some fractures treated elsewhere may not have been identified. The data include only fractures identified after primary or revision total hip or knee arthroplasty done at the Mayo Clinic and do not include fractures referred for treatment after arthroplasty elsewhere. Finally, the figures represent *raw* data from the total joint registry, and each case has not been individually reviewed by the author.

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major disruptions of the pelvis. The overall incidence of the problem is unknown.<sup>8</sup> The only series reported to date included only 13 fractures gathered from three institutions, suggesting that major intraoperative acetabular fractures are uncommon. Women predominated in that series (11 of 13) as did patients with compromised acetabular bone quality.<sup>50</sup>

Postoperative

Acute postoperative acetabular fractures are uncommon, but no incidence figures are available. These fractures appear to fall into two categories: (1) those related primarily to a traumatic event and (2) those related primarily to osteolysis. Peterson and Lewallen<sup>42</sup> reported on 11 acute postoperative acetabular fractures: 8 were around radiographically stable implants, and 3 were associated with acetabular implant loosening. None was associated with marked acetabular osteolysis.

Sanchez-Sotelo et al<sup>47</sup> reported three cases of acetabular periprosthetic fractures associated with severe pelvic osteolysis. All cases had previously well-fixed uncemented acetabular implants. In each case, severe pelvic bone loss resulting from particulate debris-associated osteolysis appeared to be the predisposing risk factor for an acute acetabular fracture that occurred with little or no trauma. This problem may increase in frequency as more patients with uncemented sockets are followed for longer periods.

Pelvic discontinuity represents a separate category of postoperative acetabular fracture characterized in most cases by a transverse acetabular fracture nonunion. Usually the fracture cannot be ascribed to a single event, and it is believed these fractures often begin as stress fractures through areas of weak deficient pelvic bone. Little has been written about this problem, but a review at the Mayo Clinic identified 29 cases of chronic pelvic discontinuity during 3505 acetabular revisions.<sup>4</sup> Risk factors for pelvic discontinuity in that series included female gender and rheumatoid arthritis. Previous therapeutic pelvic irradiation was also believed to be a risk factor.

Periprosthetic Femoral Fractures

A reliable figure for the overall rate of periprosthetic fractures associated with total hip arthroplasty is difficult to obtain. The figure is

dependent on (1) the length of time a cohort of patients has been followed after total hip arthroplasty, (2) the demographic makeup of the cohort of patients receiving total hip arthroplasty, (3) the number of revision patients included in the series, (4) the types of implants in use, (5) the technique used for implant insertion, (6) whether intraoperative or just postoperative fractures are included in the statistics, (7) the frequency of routine follow-up after operation, and (8) the threshold for prophylactic operative treatment if risk of fracture is identified. In one series of 1442 primary cemented total hip arthroplasties performed from 1968 to 1983, Löwenhielm et al<sup>34</sup> estimated the cumulative risk of postoperative periprosthetic fracture to be 25.3 per 1000 after 15 years. Data from the Mayo Clinic joint registry demonstrate that a total of 1249 intraoperative and postoperative femur fractures have occurred during or after 30,329 cemented and uncemented primary and revision hip arthroplasties performed between 1969 and the present.

Intraoperative

Intraoperative fractures occur during primary and revision hip arthroplasty but are much more common during revision operations (Table 1). The Mayo Clinic Joint Registry identified an intraoperative fracture rate of 1% in 23,980 primary hip arthroplasties compared with 7.8% in 6349 revision hip arthroplasties. Khan and O'Driscoll<sup>30</sup> reported 17 intraoperative fractures in 1751 total hip arthroplasties: 11 were during primary total hip arthroplasty, and 7 were during revisions (the denominator for both groups was not given). Fractures during both primary and revision surgeries are much more common around uncemented than

Table 1. PERIPROSTHETIC FEMUR FRACTURES AROUND TOTAL HIP ARTHROPLASTY\*

	n	Fractures	%
Intraoperative primary	23,980	238	1
Cemented	20,859	68	0.3
Uncemented	3121	170	5.4
Intraoperative revision	6349	497	7.8
Cemented	4813	175	3.6
Uncemented	1536	322	20.9
Postoperative primary	23,980	262	1.1
Postoperative revision	6349	252	4.0
Totals	30,329	1249	4.1

\*Data from the Mayo Clinic joint registry; see footnote at start of article.

cemented implants (see Table 1). Intraoperative fractures during uncemented hip arthroplasty are often a consequence of the surgeon attempting to obtain a tight press-fit of the implant; thus, some fractures are probably a necessary consequence of obtaining a sufficiently tight press-fit to gain bony stability.

Intraoperative femur fractures during primary hip arthroplasties are much more frequently associated with uncemented than cemented implants (see Table 1). The Mayo Clinic Joint Registry identified a fracture in 0.3% of 20,859 cemented primary total hip arthroplasties compared with 5.4% of 3121 uncemented primary total hip arthroplasties of many designs. Taylor et al<sup>53</sup> reported a 1.2% rate of intraoperative fracture in 605 cemented total hip arthroplasties. By comparison in a multiseries review, the same authors found a 1% intraoperative fracture rate (some of which were greater trochanter fractures) in 13,985 cemented total hip arthroplasties. Schwartz et al<sup>48</sup> reported 39 intraoperative fractures in 1318 uncemented total hip arthroplasties; the overall rate of intraoperative fracture in that series was 3.7% in primary total hip arthroplasty. Fractures associated with uncemented total hip arthroplasty usually occur during femoral canal broaching or implant insertion.<sup>18</sup> Fractures around proximally porous-coated metaphyseal filling implants most commonly occur proximally, whereas fractures around extensively coated implants designed to obtain a tight fit in the isthmus most often occur distally.

Intraoperative femoral fractures associated with revision surgery can occur during exposure or hip dislocation, implant removal, cement removal, canal preparation, implant insertion, and hip reduction.<sup>30,49</sup> Johansson et al<sup>28</sup> reported 22 intraoperative fractures: 11 occurred during cement removal, 3 during dislocation, 5 during implant resection, and 2 during reaming. Most fractures occur in bone that is weak resulting from osteoporosis, focal osteolysis, or focal bone loss of other causes. Fractures that occur during exposure or attempted dislocation are usually related to torsional forces that exceed the strength of the femur. Christensen et al<sup>9</sup> reported 10 intraoperative fractures during 159 revision total hip arthroplasties: 5 of the 10 fractures occurred during hip dislocation. Fractures associated with implant or cement removal (or both) are often technically related: Fractures are more likely when well-fixed implants are removed and when femoral geometry or de-

formity compromises the path of implant extraction.

During uncemented femoral revision, the femur is at risk for fracture at all of the same stages as cemented revision but, in addition, is at added risk during tight press-fit implant insertion.<sup>18,39</sup> Information from the Mayo Clinic Joint registry showed that an intraoperative fracture occurred during 3.6% of 4813 cemented femoral revisions and 20.9% of 1536 uncemented femoral revisions. Fracture during uncemented implant insertion is more common in revision than primary surgery because of poorer bone quality, distortions of femoral geometry, and the need for longer implants. The frequency of intraoperative fractures associated with canal preparation and implant insertion varies for uncemented implants with implant design, surgical technique, bone quality, and bone deficiency.

### *Postoperative*

Postoperative periprosthetic femur fractures seem to be increasing in prevalence, probably as a consequence of a growing population of patients with hip arthroplasties in place and a growing population of patients with compromised femoral bone around hip arthroplasties (resulting from osteolysis<sup>41</sup> or multiple revision operations). In addition, as the pool of patients with hip arthroplasties ages, there are more elderly patients with poor bone at risk for falls. Extension of total hip arthroplasty technology to younger patient populations means the pool of young active patients (who are at greater risk for high-energy trauma events) also is growing.

For reasons mentioned previously, information in the literature concerning the true prevalence of postoperative periprosthetic fractures is difficult to interpret, and different reports in heterogeneous patient populations followed for varying lengths of time have reported the prevalence to range from 0.1% to 2.1%.<sup>2,5,19,21,34,49</sup> No specific period after total hip arthroplasty has been proved to have a uniquely elevated risk for fracture,<sup>19,34</sup> and no specific diagnoses (except revision; see later) have been shown to be at significantly higher risk.<sup>34</sup> Most but not all series show a slight preponderance of women (12 of 14 in Löwenhielm's series,<sup>34</sup> 55% of 86 patients in Beal's series,<sup>3</sup> 26 of 37 in Cain's series,<sup>7</sup> 22 of 31 in Adolphson's series,<sup>2</sup> 16 of 31 in Bethea's series,<sup>5</sup> and 26 of 37 in Garcia-Cuimbrelo's series.<sup>21</sup> Of the 514 postoperative femoral frac-

tures in the Mayo Clinic registry, 302 (59%) have occurred in women.

The cause of periprosthetic femur fractures is most often a minor episode of trauma. In a series of 32 fractures reported by Adolphson et al,<sup>2</sup> 28 were associated with minor trauma, 2 were spontaneous, and 2 were associated with major trauma. In the series by Beals and Tower,<sup>3</sup> 66% of 86 fractures occurred in a fall indoors and 18% in a fall outdoors; only 8% were associated with major trauma. Cooke and Newman<sup>11</sup> found only 6 of 75 fractures around a total hip arthroplasty were associated with major trauma.

The Mayo Clinic Joint Registry identified postoperative periprosthetic femoral shaft fractures after 1.1% of 23,980 primary total hip arthroplasties and after 4.0% of 6349 revision total hip arthroplasties (see Table 1). The increased risk for fracture after revision total hip arthroplasty is probably due to compromised bone quality and focal bone deficiencies. When areas of weak bone occur in juxtaposition to the high stress areas near the tip of femoral implants, fracture risk is especially high. Certain revision techniques, such as impaction grafting, that traditionally have relied on shorter stems in revision surgery carry a risk of postoperative periprosthetic fracture.<sup>22</sup> Elting et al<sup>14</sup> reported three late fractures in 67 revision hip arthroplasties treated with impaction grafting.

A unique type of postoperative femoral fracture, late peritrochanteric periprosthetic fractures associated with well-fixed implants and particulate debris-induced osteolysis, has been reported.<sup>26</sup> Severe osteolysis of the proximal femur appears to be the risk factor for these fractures. In the future, as osteolysis occurs more commonly in association with well-fixed implants, this type of fracture may be seen more often.

## PERIPROSTHETIC FRACTURES AROUND TOTAL KNEE ARTHROPLASTY

As is the case for total hip arthroplasty, figures for the rate of periprosthetic fractures around total knee arthroplasty are difficult to obtain from the literature because such figures depend on many factors, including (1) length of follow-up time, (2) demographic makeup of the patient population, (3) total knee arthroplasty design, (4) techniques of insertion, and

(5) whether the patella was resurfaced. To date, the author is aware of no studies that have reviewed the overall rate of periprosthetic fracture around the knee. Although subject to the qualifications mentioned in the footnote at the start of this article, data from the Mayo Clinic joint registry allow some trends to be identified (Table 2): (1) About 3% of 19,810 primary and revision total knee arthroplasties performed since 1970 are known to have experienced an intraoperative or postoperative periprosthetic fracture to date. (2) The most frequently fractured bone was the femur, the next the patella, and the least the tibia. (3) Intraoperative fractures are much less common than postoperative fractures (by a factor of approximately 10). (4) Fractures during and after revision surgery are more common than during or after primary surgery. Postoperative periprosthetic fractures were roughly twice as common after revision compared with primary surgery.

## Periprosthetic Femoral Fractures

### *Intraoperative*

Intraoperative femur fractures are uncommon during knee arthroplasty. No incidence figures for these fractures are available from the literature, but data from the Mayo Clinic joint registry suggest that significant intraoperative fractures of the femur occur more often during revision than primary total knee arthroplasty (see Table 2). In the primary arthroplasty setting (for modern implant designs), most are intercondylar fractures that occur in association with placement of a posterior cruciate substituting implant that requires a notch to be cut for a posterior cruciate substituting implant. Fracture may occur if the posterior cruciate substituting housing box cut is of insufficient size to accommodate the implant or if implants or trials are not impacted squarely onto the femur. Lombardi et al<sup>33</sup> reported that an intraoperative intercondylar fracture rate of 40 in 898 experienced with one posterior cruciate substituting design was reduced to 1 in 532 with implant design and technique modifications.

In the revision setting, intraoperative femur fractures can occur during exposure or femoral implant removal, bone preparation, or placement of tightly fitting uncemented stems. Most

**Table 2.** PERIPROSTHETIC FRACTURES AROUND TOTAL KNEE ARTHROPLASTY\*

	n	Femur %	Tibia %	Patella %	Total %
Intraoperative primary	16,906	23 (0.1)	13 (0.67)	0 (0)	36 (0.2)
Intraoperative revision	2904	24 (0.8)	25 (0.8)	8 (0.2)	57 (1.9)
Postoperative primary	16,906	161 (0.9)	75 (0.4)	117 (0.7)	353 (2.1)
Postoperative revision	2904	48 (1.6)	26 (0.9)	53 (1.8)	127 (4.4)
Total	19,810	256 (1.3)	139 (0.7)	178 (0.9)	573 (2.8)

\*Data from the Mayo Clinic joint registry; see footnote at start of article.

involve a fracture of a condyle or epicondyle through weak or compromised bone.

### Postoperative

Postoperative fractures of the femur most commonly involve the supracondylar region of the femur but may occasionally extend to the diaphysis, particularly if a stemmed femoral implant is in place. In contrast to most subjects related to periprosthetic fractures, a considerable amount has been written about prevalence and risk factors for supracondylar fractures after total knee arthroplasty.

The prevalence in different series varies and in many is difficult to ascertain because of the methods by which patients were entered into the series. Figgie et al<sup>17</sup> found 24 supracondylar fractures among 762 total knee arthroplasties (1.8%) after a mean of 6 years.

The following patient groups appear to have elevated supracondylar fracture risk: elderly women, patients with osteoporosis, patients with rheumatoid arthritis, and patients with neurologic conditions.<sup>13</sup> Osteolysis may also lead to fracture of the femur.<sup>43</sup> Data from virtually all series show a preponderance of female patients<sup>51</sup>: In Culp's series,<sup>12</sup> 49 of 58 patients; in Merkel's series,<sup>36</sup> 29 of 36; in Nielsen's series,<sup>40</sup> 12 of 16; and in Sisto's series,<sup>52</sup> 12 of 15. Mayo Clinic joint registry data show that 129 of 161 postoperative femur fractures around total knee arthroplasties occurred in women. The series by Culp et al<sup>12</sup> demonstrated 17 of 61 fracture patients had neurologic conditions, with seizures and ataxia being the most common. In the series by Cain et al,<sup>7</sup> a fall led to the fracture in 12 of 14.

The amount an anterior notch of the femur increases the risk of supracondylar fracture has been debated. Aaron and Scott<sup>1</sup> reported 42% of patients with a deep anterior resection went on to fracture. Culp et al<sup>12</sup> reported 27 of 61 knees with a supracondylar fracture also

had a notch, but the denominators for numbers of patients with and without a notch were not available. In distinction, Ritter et al<sup>46</sup> demonstrated no relationship between an anterior notch and supracondylar fracture in 670 knees. Of those knees (all treated with cruciate condylar total knee arthroplasty from 1975 to 1983), 20.5% had an anterior notch of less than 3 mm, but only two fractured: one in the notched group and one in the unnotched group.<sup>44</sup> Moran et al<sup>38</sup> found a notch in only 2 of 29 patients with a supracondylar fracture. Comparing series may be difficult because different surgeons may define what constitutes a notch differently. Most agree, however, that a notch should be avoided, particularly in patients with weak bone.

### PERIPROSTHETIC TIBIA FRACTURES

Little has been written about periprosthetic tibial fractures around total knee arthroplasty. A Mayo Clinic report on the subject identified 102 fractures, 19 of which were intraoperative and 83 postoperative.<sup>16</sup> The fractures occurred in 73 women and 29 men.

Intraoperative tibial fractures were observed during tibial preparation, trial reduction, and implant placement as well as during cement removal in revision total knee arthroplasty. Insertion and removal of long-stem implants accounted for about one half of the fractures. Sixty-one of the 102 tibial fractures in the same series involved a tibial plateau (most often medial). Fifty of these fractures occurred postoperatively, most occurred around a loose implant, a few were associated with a major traumatic event. Twenty-two of the 102 fractures involved the metaphysis or proximal diaphysis: Most occurred postoperatively (15) and were associated with a loose-stemmed tibial implant. Seventeen of the 102 fractures

were located in the diaphysis; most (15 of 17) occurred distal to well-fixed tibial implants.<sup>21</sup> Diaphyseal tibial fractures may also occur when uncemented stems are press-fit into the tibia<sup>15</sup> or in association with stress risers created by tibial tubercle osteotomies.<sup>45</sup>

## PERIPROSTHETIC PATELLAR FRACTURES

Almost all patellar fractures associated with primary total knee arthroplasty occur postoperatively, although patellar fractures can occur intraoperatively during revision surgery. In the Mayo Clinic joint registry, no intraoperative patellar fractures were identified in 16,906 primary total knee arthroplasties, and only 8 were reported in 2904 revision total knee arthroplasties (see Table 2).

The incidence of postoperative periprosthetic fractures varies in different series.<sup>10,31,44</sup> Healy et al<sup>25</sup> reported 5 of 211 (2.4%) knees developed patellar fractures with a mean follow-up time of 37 months after total knee arthroplasty. Lynch et al<sup>35</sup> reported patellar fractures in 1.8% of 281 resurfaced patellae, Brick and Scott<sup>6</sup> reported 15 patellar fractures in 2887 primary total knee arthroplasties (0.5%), and Tria et al<sup>54</sup> reported 18 in 504 total knee arthroplasties (3.6%). In most cases, fractures are associated with a resurfaced or previously resurfaced patella; in a report by Grace and Sim,<sup>24</sup> the rate of fracture without patellar resurfacing was only 0.05%, statistically significantly less ( $P < 0.05$ ) than for resurfaced patellae. The same authors also demonstrated that patellar fractures were more common after revision than primary total knee arthroplasty.

Factors thought to be associated with patellar fractures are numerous. Underresection or overresection of the patella at the time of resurfacing may contribute.<sup>55</sup> Osteonecrosis of the patella may lead to fracture. Specific patellar designs with a large central peg may increase the risk of patellar fracture. Tibial and femoral implant malalignment (either angular or rotational) can dramatically increase forces on the patellofemoral articulation and may increase the risk of fracture.<sup>23</sup>

Several studies of patellar fractures reported a predominance of female patients: In Brick's series,<sup>6</sup> 13 of 15 were female; in Goldberg's series,<sup>23</sup> 28 of 35 were female; and in Hozack's series,<sup>27</sup> 13 of 18 were female. In distinction, data from the Mayo Clinic joint registry dem-

onstrate that in contrast to postoperative femur and tibia fractures (in which women predominate), postoperative patellar fractures were more common in men: 73 of 117 patellar fractures after primary total knee arthroplasty occurred in men, and 30 of 53 postoperative patellar fractures after revision total knee arthroplasty occurred in men.

## CONCLUSIONS

Periprosthetic fractures around the hip and knee arthroplasties are being seen with increasing frequency. The prevalence and risk factors for fracture vary by anatomic site. The frequency of certain fracture types and locations are technique or implant design specific, whereas for other fracture types and locations the frequency and cause relate to bone quality and risk of trauma. An emerging problem, fractures associated with periprosthetic bone loss and osteolysis have now been reported around both the hip and the knee.

Understanding the factors associated with fracture may lead to prevention. Adjustments in technique or implant design may prevent some intraoperative fractures. Efforts to restore compromised bone stock may also prevent postoperative fractures in the high-risk group of patients treated with revision joint arthroplasty. Finally, proper follow-up of the ever-growing population of patients with arthroplasties may identify patients at risk for fracture and allow intervention before a fracture occurs.

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