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# Management of Severe Osteoporosis in Primary Total Hip Arthroplasty

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**Abstract** Severe osteoporosis is becoming a common problem faced by surgeons performing primary hip arthroplasty. As the population ages, osteoporosis is increasing, especially as the population aged more than 80 years increases. Patients may need a total hip replacement to treat osteoarthritis or an acute femoral neck fracture. Recent data have shown an advantage to hip replacement in this population. Although uncemented and cemented designs of femoral prostheses have been used successfully, there is a high rate of periprosthetic fracture associated with the use of uncemented stems in patients with osteoporosis. Successful replacement requires knowledge of the particular stem type used in the weakened proximal femur. Total hip replacement for fracture also has a higher rate of dislocation. Additional study is required to determine if a particular uncemented stem design is better than others in this scenario or whether more use of cemented stems would help to limit periprosthetic fracture.

**Keywords** Osteoporosis · Total hip arthroplasty · Total hip replacement · Osteoarthritis · Femoral neck fracture · Hip fracture · Periprosthetic fracture

## Introduction

The number of people with osteoporosis is rising, especially in older age groups, and many of them also have osteoarthritis [1, 2]. Simultaneously, the population is aging: the "baby boomer" generation is leading to an increase in the percentage of the population that is older, and there has been a dramatic rise in the number of people more than 80 and 100 years old [3]. This older age group also frequently has osteoarthritis of the hip. Of individuals more than 60 years old, 10 % of the men and 18 % of the women are thought to have severe arthritis [4]. The Organisation for Economic Co-operation and Development reported an average of 154 hip replacements per 100,000 people in 2009, although this statistic varies by country [4]. Overall, the trend is for an increasing number of surgeries over time. This aging process has led to an increasing number of patients with osteoporosis who need hip replacement for osteoarthritis.

The most common diagnosis for hip replacement is osteoarthritis of the hip. Other diagnoses include rheumatoid arthritis, osteonecrosis, post-traumatic arthritis, and fracture of the proximal femur. Hip fractures are osteoporotic fractures and lead to substantial morbidity and mortality. Worldwide, the number of hip fracture is thought to have increased as the overall population ages [5–7]. However, there may be a plateau of this rise in the United States, possibly because of bisphosphonate use [8]. The location of the fracture is critical to the treatment used. Intertrochanteric and subtrochanteric fractures are treated with internal fixation. The treatment of femoral neck fractures is controversial, and options include internal fixation, hemiarthroplasty, and total hip arthroplasty. Recent results have shown better outcomes with total hip replacement (THR) than fracture fixation [9, 10] or partial hip replacement [11, 12, 13•] in active, lucid individuals. The primary risk of internal fixation is the need for additional surgery in the future, which is typically conversion to a total hip arthroplasty [14•]. This information about improved results with total hip arthroplasty is leading to increased numbers of arthroplasty used for the treatment of hip fractures.

Other conditions can create osteoporotic bones and the need for hip replacement. For example, patients requiring long-term steroid use from organ transplantation or rheumatological conditions may develop osteonecrosis and osteoporosis simultaneously. Osteogenesis imperfecta is a condition caused by a defect in collagen that leads to very weak bones, hip deformity, and arthritis.

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The surgeon performing THR needs to understand and address the potential pitfalls that osteoporosis can bring to performing hip replacement. This article will discuss the components of hip replacement, address the use of different stem types, and provide suggestions for the management of common complications of hip replacement in the profoundly osteoporotic femur.

## Types of Components and Stem Choices

The typical hip replacement consists of four components. The acetabular and femoral components are anchored on the bone, whereas the head and liner are attached to the femoral and acetabular components, respectively. The liner and the head make up the bearing surface of the hip. For patients with osteoporosis, the bearing surface should uniformly be of highly cross-linked polyethylene and cobalt chrome steel. There is little role for ceramic or other bearing surfaces in individuals with a functional life expectancy of 15–20 years. This bearing surface has been shown to be a reliable, long-lasting surface with few complications. Metal on plastic has been recommended as the "bearing of choice" for patients with hip fracture [15]. Uncemented acetabular components have been shown to have good success in osteoporotic individuals. The biggest problem is the placement of the femoral component and the risk for periprosthetic fracture during or after surgery. Several factors play a role in the risk of femoral periprosthetic fracture, including the decision to use a cemented or an uncemented stem and the exact design of uncemented stem. Proximally coated uncemented stems place a higher stress riser on the proximal femur and increase the risk of fracture.

### Acetabular Component

Both uncemented and cemented cup fixation can be successfully used in patients with osteoporosis. In the United States, the acetabular component is most commonly anchored with uncemented fixation. As long as adequate fixation is achieved with or without screws, uncemented acetabular components have been shown to be a long lasting and durable solution. Insertional fracture is an uncommon complication that may present itself when bone quality is poor.

Care should be taken with insertion to prevent periprosthetic acetabular fracture. Fracture has been noted with particular cup designs that are not hemispherical [16]. Consideration should be given to the amount of under-reaming used to obtain a press fit. Osteoporotic bone is more brittle and less forgiving. The surgeon may consider reaming to a larger diameter so that the cup will impact more solidly in the weakened bone and have less chance of fracture. For instance, for the insertion of a 50-mm cup, standard insertion technique may recommend reaming to 48 mm. In osteoporotic bone, this 2-mm mismatch may lead to fracture, whereas reaming to 49 mm may allow for the cup to be impacted without fracture. In such cases, supplemental screws may help to give added fixation. Fixation of an acetabular fracture is difficult and usually includes a combination of plate fixation of the posterior column of the acetabulum to give enough stability to place a cup and revision cup placement with multiple screws. If there is concern about the press-fit of a cup, supplementary screw fixation should be used. It has been suggested that newer porous metal surfaces also may provide better ingrowth surfaces and higher frictional properties [17], which may also be useful in the profoundly osteoporotic acetabula.

### Femoral Component

The femoral component is the focus of most debate in the presence of severe osteoporosis. The shape of the osteoporotic femora is different than that of the non-osteoporotic femora. As the bone density decreases, the bone reacts by widening and having a thinner cortex [18]. A widely used classification system was developed by Dorr [19••]. A Dorr A bone is champagne flute shaped, with wide cortices. A Dorr B bone starts to widen on the anteroposterior (AP) view, whereas a Dorr C bone is a "stovepipe femur". In Dorr C bone, the bone is widened on the AP and lateral planes, and the cortex becomes very thin (Fig. 1). When examined as a cadaveric specimen, the bone can be thin enough to see through. The Dorr classification has been shown to correspond with bone mineral density [20].

**Fig. 1** This anteroposterior radiograph of a hip with osteoporosis shows Dorr C bone. Note the widened femoral canal and very thin cortices. These parameters make the placement of uncemented prosthesis challenging and increase the perprosthetic fracture rate

The Dorr C stovepipe femur is consistent with severe osteoporosis, and this shape creates problems for stem fixation. One choice is to cement the femoral stem into the bone, which has been done with success [21]. The only limitation is when the stem size becomes so wide that even the largest cemented stems begin to have a very thick cement mantle. Recommended mantles are 1–2 mm, and severely undersized femoral components may develop early loosening [22, 23]. Cementation becomes difficult, then, in those with profoundly wide and thin cortices. Severe osteoporosis has been shown to correlate with long-term stem loosening of cemented stems [24]. In general, cementation of the femoral component is a reliable method for the osteoporotic bone.

Dorr C bone provides challenges for the insertion of uncemented stems [25]. With the shape alteration of the bone, the canal widens, but the hip center stays the same. However, larger size stems increase in neck length and offset with width, which may create a mismatch and potential for excessive leg lengthening. Careful templating should be performed to make sure that the larger size stem needed to fit the bone does not create a leg-length inequality, which can mean using a lower neck cut so that the stem can be sunk to an appropriate level. The two main concerns with the use of uncemented stems are implant subsidence and fracture. Subsidence occurs when a tight enough fit is not achieved; it can lead to stem slippage and the excessive motion that prevents stem ingrowth. A recent radiostereometric analysis study evaluated subsidence and osteointegration in a group of 39 patients with severe osteoporosis undergoing hip replacement [26•]. In that study, an anatomically shaped hydroxyapatite coated implant (ABG-II, Stryker, Kalamazoo, MI) was used with implantation of tantalum RSA beads. The patients were evaluated for 2 years after surgery. Stems were found to have delayed integration and less initial stability than is seen in younger patients. The delayed integration and increased instability correlated with age and severity of bone mineral density loss. The authors suggested that the anatomically designed stem may in particular not fit the cortical shape of the osteoporotic femur.

Case series have been reported with many different uncemented stem types in Dorr C osteoporotic bone. Dalury et al. [27] have shown excellent results using a flat double-tapered stem design in 60 patients with a follow-up of 6 years. Keisu and colleagues [28] showed excellent results for 69 hips at 5 years after replacement; their patients were all more than 80 years old. In another study of 33 hips with Dorr C bone treated with a tapered titanium stem, no revisions for loosening or fractures were seen in 13 years of follow-up [29]. Similar results have been shown for tapered stems for hemiarthroplasty [30] and for THR in older adults [31]. In another study, osteoporosis did not seem to cause early subsidence using a double-tapered stem [32]. Meding et al. [33] investigated the long-term outcomes of 2321 hips implanted with a straight titanium tapered stem. These hips were divided by Dorr classification to assess bone quality, and 127 were determined to be Dorr C bone. No differences were seen in outcomes, stem stability, or loosening among groups. In one study, the Omnifit HA stem (Stryker-Howmedica-Osteonics, Rutherford, NJ), which is a hydroxyapatite-coated stem with mostly proximal fixation, performed well in a limited series of nine patients with a 9-year follow-up [34]. These patients all had Dorr C type bone. Another hydroxyapatite coated stem, the Furlong stem (JRI Orthopaedics, Sheffield, UK), has also shown good results when used for hemiarthroplasty in patients after hip fracture [35]. A shorter proximally coated stem has been shown to have good results in a case series of patients more than 70 years old, although the study did not measure the type of bone or bone density [36].

Extensively porous-coated designs are also thought to work well in patients more than 65 years old [37]. Although these designs have not been studied exclusively in osteoporotic individuals, one study investigated the results of larger diameter stems [38]. A portion of those studied were osteoporotic individuals, and good results were reported. However, there is concern that in Dorr C type bone more stress shielding may occur because of the very large stem placed in a an overall weakened bone [37, 39, 40]. In one study of patients more than 65 years old who had fully coated stems, stress shielding was seen in 45 of 174 (26 %) of hips at 2 years [37]. This finding did not correlate with failure, loosening, or reoperation of the hip replacement. The long-term effects of stress shielding in these patients is unknown.

It is important to note that in all of these case series, the stems were inserted by expert surgeons who were very familiar with the stem used in the study. Different results are seen when data are amalgamated into nationwide databases that include surgeons with differing levels of experience and familiarity with a specific implant. In Sweden, uncemented stem design and age, which presumably reflect osteoporosis, are major factors in the development of periprosthetic fracture and stem failure [41]. This information should be critical to stem selection by individual surgeons. For the profoundly osteoporotic femora, the surgeon who is unfamiliar with the nuances of a particular uncemented stem is probably better off using cemented fixation to achieve stem stability and to reduce the risk of fracture.

## Common Complications

### Periprosthetic Fracture

Periprosthetic fracture has been shown to be a major complication of placing a femoral stem into an osteoporotic bone. The fracture rate is approximately 4 % after hip replacement [42]. Risk factors for fracture have been well categorized and include age, female gender, uncemented implants, and revision implants [43]. Patients with periprosthetic fracture are at much higher risk of death than those who undergo arthroplasty but do not fracture [44].

Periprosthetic fracture seems to be related to osteoporosis of the femur, as would be expected, and may occur during or after surgery. Intraoperative fractures have been classified and described, and severity may range from inconsequential to catastrophic [45]. Insertional fractures most commonly occur in the calcar region of the hip. Osteoporotic bones are very brittle and much more susceptible to intraoperative fracture than normal bone. If this fragility is not recognized at the time of stem insertion, it can lead to propagation of the fracture, with frank fracture or stem loosening. When the fracture is noted during surgery, the stem should be removed and a cable or wire should be placed around the calcar. If the fracture has not propagated, the surgeon may be able to reinsert the stem successfully. Another option is to change to a fully coated prosthesis so that stable distal fixation is achieved. If the fracture propagates, plate fixation may be necessary, with a revision implant to give adequate stability. Intraoperative radiographs should be taken to ensure that the stem appears stable and that the fracture is not more severe than perceived under direct vision. Prevention of fracture is the best option, and careful preoperative templating [46] or selection of an uncemented stem may help to reduce fracture rates.

Late peri-prosthetic fracture is a major concern in patients with hip replacement and osteoporosis. The risk of periprosthetic fracture is increased in women more than 70 years old, as seen in more than 50,000 patients in the Scottish national database between 1997 and 2008 [43]. This risk is thought to be the result of the high prevalence of osteoporosis in this group. Recent studies have shown that late fracture risk is lower for cemented than for uncemented stems, as has been clearly shown for hemiarthroplasty [47•, 48, 49•] and total hip arthroplasty [41, 50].

Biomechanical studies have also shown a protective effect of cement in terms of load to failure in osteoporotic bones [51]. Research on uncemented stems has not shown clear advantages to any one stem type over another [52].

### Dislocation

Dislocation is another major complication of THR. In general, the rate of dislocation depends on the surgical approach used [53, 54]. Posterior approaches are thought to have a higher dislocation rate than do anterolateral or anterior approaches. Careful capsular repair decreases the risks of dislocation when a posterior approach is used. Head size also affects dislocation rates: smaller heads have a higher dislocation risk than do larger heads [15]. In elective THR, dislocation is a risk well known to the reconstructive surgeon, and careful attention is paid to positioning the acetabular and femoral components in the safe zone to minimize dislocation risks [55].

The more aggressive use of THR for proximal femoral fracture for osteoporotic individuals has brought to light the importance of dislocation as a complication. A large head size decreases the dislocation risk, and hemiarthroplasty is much more stable than THR. The risk of dislocation in THR for fracture has been reported to be up to 8 %, which is far higher than that in THR for osteoarthritis [14, 53, 56•]. One possible factor for this discrepancy may be surgeon familiarity with THR. The surgeon performing this procedure for fracture repair may not be a full-time reconstructive hip surgeon; therefore, he or she may have far less experience and thus may have higher complication rates. Another theory is that the capsule of the non-arthritic hip is more elastic and does not protect against dislocation as in the osteoarthritic patient. In either case, if dislocation rates are too high, the benefits overall to a population of patients undergoing total hip versus hemiarthroplasty might not be realized [57]. Attention to additional surgeon education in the techniques of total hip is needed to decrease the dislocation risk in these fracture patients.

## Conclusion

Hip arthroplasty is becoming more common in patients with severe osteoporosis. Excellent results have been shown with cemented and uncemented femoral implants. Peri-prosthetic fracture, however, is becoming more common and is a worrying complication, and it occurs more commonly in patients with uncemented than cemented femoral prostheses. Great care should be taken with the use of uncemented prostheses that are more susceptible to fracture in these patients than they are in patients with better bone. When THR is performed for fracture, dislocation rates have also been worryingly high. Careful consideration should be given to the bone shape and the skill of the surgeon in performing THR for the osteoporotic patient, particularly after hip fracture.

**Conflict of Interest** Simon C. Mears declares he has no conflict of interest.

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- •• Of major importance

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