MENTORS IN ORTHOPEDICS

PECULIARITIES OF TOTAL HIP ARTHROPLASTY IN PATIENTS WITH LOW BONE MASS

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SUMMARY

Background: Total hip arthroplasty (THA) is frequently performed in elderly populations where the prevalence of systemic bone loss is high. Despite the clinical success of THA, the impact of undiagnosed osteoporosis and osteopenia on implant stability remains a significant concern, as these conditions may be underestimated due to infrequent preoperative bone mineral density (BMD) screening.

Objective: This review aims to evaluate the incidence of low bone mass in THA candidates, analyze the patterns of periprosthetic bone remodeling, and examine the efficacy of modern uncemented acetabular components in patients with compromised bone quality.

Key Points: Research indicates that 21–32% of patients with severe osteoarthritis also have osteoporosis. Low BMD is associated with increased migration of uncemented components and higher risks of intraoperative periprosthetic fractures. Postoperative bone remodeling studies show significant BMD reductions in Gruen zone 7 and periacetabular regions within the first three years. While porous tantalum and titanium implants are designed to enhance biological fixation through biomimetic porosity and low Young's modulus, their performance in osteoporotic bone is less understood. Increased bone resorption and proinflammatory cytokines in these patients may elevate implant micromobility beyond the 150μm threshold, potentially leading to fibrous tissue formation instead of osseointegration.

Conclusion: Low bone mass significantly influences both intraoperative risks and long-term implant survivorship. Although highly porous acetabular designs offer theoretical advantages for biological fixation, further clinical and experimental studies are required to establish definitive protocols for managing THA in patients with reduced BMD.

KEYWORDS

Arthroplasty, Replacement, Hip; Osteoporosis; Bone Density; Acetabulum; Osseointegration

Incidence of osteoporosis and osteopenia among patients undergoing total hip arthroplasty

Total hip arthroplasty (THA) is one of the most common and clinically successful surgeries in the world [7]. In the United Kingdom, the average age of patients undergoing this procedure is 69.8 years for women and 67.6 for men. In 90% of patients, the indication for surgery is osteoarthritis, and 60% of patients are women [8]. The situation is very similar in the United States, where most patients are aged 55-74 (accounting for 57% of the total number of total hip arthroplasty procedures) [9].

This means that the majority of THA patients are women over 55 years of age. Therefore, we need to consider the incidence of osteoporosis and osteopenia among this patient population. In a clinical study conducted in the United States, 25% of women who underwent THA had latent osteoporosis [10]. Researchers in Finland obtained similar results: of the 53 postmenopausal women who underwent cementless THA, 28% had osteoporosis and 45% had osteopenia [11]. It is estimated that 21–32% of patients in the world with severe osteoarthritis have osteoporosis [12], but figures are probably underestimated due to insufficient evaluation of bone tissue in patients before THA. A survey of 433 orthopaedic surgeons in Switzerland, Austria, New Zealand, Macedonia and Estonia found that 60% of respondents considered it important to take BMD into account before performing THA, but only 4% actually prescribed bone densitometry [13].

In prospective clinical studies, it has been found that low mineral density leads to aseptic loosening of the stem [14] and acetabular component [15]. Continuous acetabular component loosening was recorded within 3–12 months post cementless hip arthroplasty in women with low bone mineral density (BMD), but only within the first three months for those with normal BMD[15]. Similar results were obtained by researchers from China [16]. According to some scientists, loosening of the acetabular component can lead to late loosening of the implants [17].

In addition to postoperative complications, patients with low BMD may also suffer intraoperative complications, the main one being intraoperative periprosthetic fracture of femur, the incidence of which is 0.3–7.8% [18]. Intraoperative fracture of the acetabulum is rare (0.29% in the United States) [19].

In osteoporosis patients undergoing THA, US surgeons use both cemented and uncemented fixation for the acetabular component [20]. However, cemented fixation is the gold standard in elderly patients [21]. Some researchers believe that new porous acetabular components can improve the longevity of uncemented fixation [20].

Bone tissue remodelling around the implants after THA

Bone remodelling around the stem after uncemented THA is well studied, but loss of bone tissue is not always detected. A recent study found a decrease in BMD in Gruen zones 1, 5, 6 and 7 within 13.3 years for several types of uncemented stems [22] (Fig. 1a). In patients with osteoporosis or osteopenia at 2 years of follow-up, a 23% reduction in BMD was found in Gruen zone 7 after uncemented THA [23].

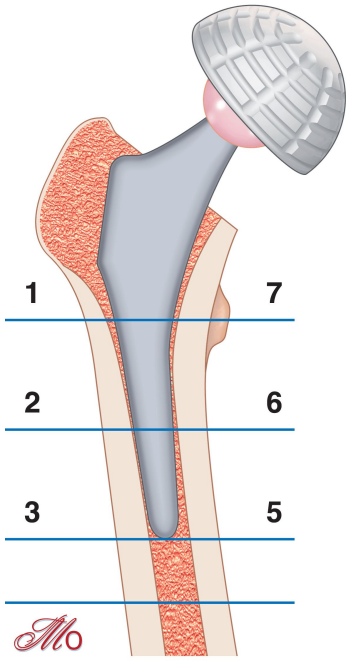

Figure 1. Gruen zones in the proximal femur (a). Adapted from (a) Alm J.J., et al., 2009 [23]; (b) Mueller L., et al., 2006 [28].

Another 10-year study (80 women aged 55–75 years) found that the greatest bone loss occurred in Gruen zone 7 after exactly 2 years, but the bone gradually recovered to baseline status 10 years after surgery [24]. The authors did not report any osteoporosis or osteopenia in their patients, but the exclusion criterion was the absence of metabolic bone disease. Therefore, it is likely that the results obtained are typical of normal bone tissue.

The most long-term study found that 20 years after THA, BMD increased by 11.19% in Gruen zone 7 and by 22.14% in Gruen zones 5 and 6 [25]. This study was performed in a small number of patients (8 women and 6 men, aged 66.2–82.3), with osteoporosis as an exclusion criterion. One possible conclusion is that bone loss does not positively correlate with length of implant survivorship in cases of normal bone tissue. We have not found similar studies of patients with low BMD.

Given the results of studies into the structure of the proximal femur of osteoarthritis patients with normal BMD [26] and reduced BMD [27], bone remodelling around the implants appears to occur in different ways. Patients with osteoarthritis or osteoporosis have architectural microdifferences in the subchondral bone of the femoral head [26]. The combination of osteoarthritis and osteoporosis decreases BMD and the strength of the femoral head [27].

The best clinical outcomes after THA are seen in patients with a high density of bone tissue in the acetabular area [29]. This reduces the risk of acetabular loosening, so it is important to analyse the remodelling of bone tissue around the acetabular cup at different times after THA. All these studies involved a small number of patients with uncemented acetabular cups. Quantitative computed tomography (QCT) (see Table 1) was used to estimate bone tissue density around the acetabular cups.

Authors	Number of patients	Follow-up	Changes in BMD of cancellous bone relative to the cup
[28]	26	1,1 years	↓18 % ROI 3 ↓30 % ROI 2 ↓35 % ROI 1
[29]	54 hips	3 years	↓52 %
[30]	26	1,28 years	↓20-33 %
[31]	23	2,2 years	↓43 % ROI 1 ↓53 % ROI 2
[32]	25	1, 3, 10 years	At three years : ↓37 % ROI 3 ↓60 % ROI 1 ↓71 % ROI 2 No change between Year 3 and 10

Interestingly, a study by Kress et al. [2011] found that there were no changes in BMD around the acetabular cups between 3 and 10 years of follow-up [32]. Similar results were obtained [24] for the stem. Bone remodelling of the acetabulum and proximal femur after THA is likely to follow a similar pattern.

Age may be a risk factor for loss of cancellous bone in ROI 3 around the cup [29], but upon analysing these studies, we find that the greatest bone loss occurs in ROI 1 and 2 (dorsal and ventral) within the first three years after surgery (Fig. 1b).

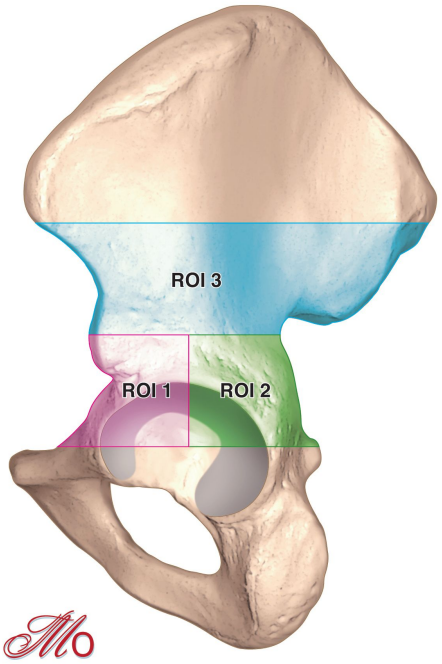

Figure 1. zones around the acetabular cup (b). Key to regions of interest (ROI): ROI 1 - ventral cup, ROI 2 - dorsal, ROI 3 - cranial. Adapted from (a) Alm J.J., et al., 2009 [23]; (b) Mueller L., et al., 2006 [28].

It remains unclear whether bone remodelling after THA in patients with reduced BMD differs from the results obtained by these authors. But given that bone loss can range from 20 to 60% in the first three years (see Table 1), the risk of post-THA complications increases in case of reduced BMD in this zone.

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Particular features of modern uncemented acetabular cups and their use in patients with low bone mass

Modern uncemented components are designed to improve biological fixation. This means a stable press-fit of the cup in the acetabulum, with bone ingrowth into the acetabular cup.

More and more studies show the advantages of porous implants for uncemented fixation [34–37].

Porous acetabular components are designed to mimic native bone structure. They have a porosity of 60-80% [38], which is similar to that of cancellous bone (75-90%) [33]. A certain pore size (more than 500μm) and shape are important for bone ingrowth and subsequent biological fixation [39–41]. In addition, the material from which the cup is made can also induce osseointegration. In particular, tantalum induces the differentiation of osteoblasts (cells that form bone tissue) from osteoprogenitor cells [42,43].

An important issue is the survival of acetabular cups in patients with low bone mass (osteopenia or osteoporosis). In general, the pore distribution in these implants mimics normal bone tissue [38], but in patients with osteoporosis, the lower number of trabeculae mean they are spaced further apart [44]. The development of porous materials is aimed not only at improving osseointegration, but also at reducing the risk of stress-shielding [45]. However, the mechanism of action is not understood when the bone has an osteoporotic structure. Furthermore, in patients with osteoporosis or osteopenia, bone elasticity is lower compared to normal bone [46]. Porous implants have a low Young's modulus which is as close as possible to that of normal cancellous bone. It is not known which acetabular component best suits the physical characteristics of the bone tissue in the hip of a patient with low bone mass.

Most modern uncemented acetabular components have a press-fit design, allowing a gap of less than 1 mm between bone and cup [37].

This is especially important in cases of osteoporosis since it provides biological fixation and long-term survival of the implant. At this distance, micromobility of the implant (40-70μm) induces bone ingrowth. Increasing the micromobility to 150μm leads to the formation of fibrous tissue [47]. In an experimental study in dogs, it was found that 500μm micromobility causes fibrous cartilage to form on hydroxyapatite-coated titanium implants 4 weeks after implantation [48], which in turn suppresses the formation of bone tissue. Patients with low bone mass have an increased rate of bone metabolism, which means an increase in bone resorption and possibly an increase in the distance between cup and bone. This, in turn, increases micromobility. Thus, in women with postmenopausal osteoporosis and in patients with rheumatoid arthritis, high blood levels of TGF-β [49], a

proinflammatory cytokine that activates the differentiation of osteoclasts (bone resorbing cells) from precursors through RANKL and increases bone resorption, have been confirmed [50].

Experimental studies have compared different types of porous metals used for modern acetabular components [51-53], but only under the conditions of normal bone tissue. At the same time, a large number of experimental studies have been performed on an oestrogen-deficient model (osteoporosis/osteopenia model) using the same titanium as for dental implants [54-57]. The simulated osteoporosis was found to inhibit the formation of cancellous bone tissue around the implant within 4–24 weeks after implantation.

This is important for understanding the osseointegration of acetabular components into the acetabulum, which is predominantly represented by cancellous bone tissue. However, given the large number of implants available, it remains unclear which is the best for patients with low bone mass.

Low bone mass in patients undergoing THA due to osteoarthritis is therefore an important factor influencing the occurrence of intraoperative (periprosthetic fractures, acetabular fractures) and postoperative (acetabular cup and stem loosening) complications. Implant survival in such patients may be reduced due to greater resorption of bone tissue around the implant, which leads to micromobility and loosening. In addition, there is an inhibition of bone ingrowth, which is an important condition for the osseointegration of porous acetabular components with a press-fit design. This is certainly important given that 21–32% of patients in the world with severe osteoarthritis, most of which undergo THA, have osteoporosis.

However, despite the clinically-proven negative effect of low bone mass on the success of uncemented THA, as well as on implant survivorship, there is a lack of studies that clinically or experimentally evaluate the benefits of using certain types of acetabular components in such conditions. Bone tissue ingrowth around the acetabular cup in such patients after THA has not yet been studied. However, it has been shown bone tissue loss in this area in patients with normal bone mineral density can reach 20–60% in the first three years after THA. Further studies are therefore needed into changes in bone mineral density around the acetabular components in patients with osteoporosis and osteopenia, to determine the feasibility of using highly porous acetabular components.

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