New Polys and Large Heads: Clinical Aspects

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Total hip replacement (THR) has become one of the most successful procedures in the last decades (Learmonth et al. 2007). Sir John Charnley developed low-friction arthroplasty using cemented fixation, a 22.225 mm stainless-steel femoral head and an all-polyethylene (PE) cup during the early 1960s of the last century, an operation with excellent long-term results worldwide (Charnley 1961) (Fig. 9.1). Cemented THRs usually show higher survivorship rates than uncemented designs; nevertheless some contemporary implants are providing very low rates of loosening with their improved primary and secondary bone fixation. In a study from the Swedish Hip Arthroplasty Register, Hailer et al. observed increased use of uncemented THR despite a lower revision rate at 10 and 15 years (Hailer et al. 2010). In their analysis they found better results for cemented arthroplasties regardless of the age or the diagnosis of the patient; when they assessed the cup and the stem, they concluded that the worse outcomes of uncemented THR were due to a higher revision rate of the cup produced by wear-related problems. So the most important problem in a long term is PE wear in both cemented and uncemented THRs as this is the main source of osteolysis and loosening (Harris 1995).

9.1 Polyethylene Wear

Conventional PE is gamma sterilised in air, a method that favours cross-linking but produces free radicals that can oxidise in vivo and decrease the mechanical properties of the plastic. This process would start the process of wear debris that is the principal

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Fig. 9.1 Radiograph of a female patient who underwent surgery at our hospital with a low-friction arthroplasty at 32 years of age secondary to congenital hip disease at 30 year of follow-up. Left hip was operated 15 years later

cause of THR loosening (Harris 1995). In clinical radiographs we can evaluate femoral head penetration into the PE liner by analysing wear through the years. Different methods have been used since the uniradiographic method by Charnley and the latest digitised methods, including radiostereometric analysis (RSA) (Charnley and Cupic 1973; Charnley and Halley 1975; Livermore et al. 1990; Dorr and Wan 1995; Martell and Berdia 1997; Digas et al. 2004). The validity of radiological measurement was reported later in experimental in vitro studies that determined that a fixed position of the x-ray beam reduces error in phantom studies, but in clinical radiographs, patient positioning is slightly different in each follow-up radiograph, so measurements of different clinical radiographs from the same patient are not as precise (Wan et al. 2006). Sychterz et al. reported that femoral head penetration over the years is divided into so-called bedding-in and true wear: in the 18–24 months after the operation, femoral head penetration is due to creep, the deformation of material without any loss of material, and after this period, wear, the removal of material subjected to mechanical stresses, would appear (Sychterz et al. 1999). In another comparative study, the analysis of sequential femoral head penetration into a conventional gamma sterilised-in-air PE, matched to a 28- or 32-mm metallic femoral head with uncemented hemispherical cups with good long-term fixation, was evaluated (García-Rey 2010). Measurements were done using digitised radiographs and concentric circles (Kim et al. 2001). Findings showed that wear during the early period was much higher than mean linear annual wear in every case, so we must identify this phenomenon when measuring polyethylene wear in any study.

Although different factors such as the age of the patient, diagnosis, physical activity or the position of a vertical cup with a postoperative acetabular abduction angle higher than 50° have been related to higher rates of PE wear, the type of THR and femoral head size are probably the most important. For conventional PE, cemented arthroplasties with 22- or 28-mm femoral heads produce lower wear rates than an uncemented THR with a 32-mm femoral head at a minimum follow-up of 10 years, and this is also true for the appearance of osteolysis (Oparaugo et al. 2001). A study from the Norwegian Register showed that the Charnley cup had lower

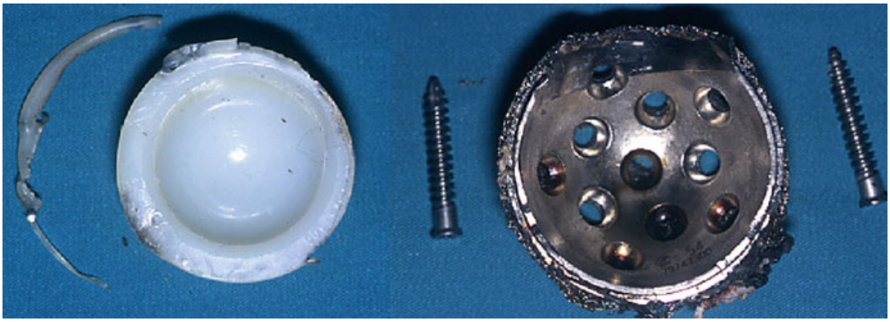

Fig. 9.2 Conventional polyethylene 32-mm liner rupture in a first-generation porous-coated uncemented cup

revision rates than other newer implants probably due to the low wear rate (Espehaug et al. 2009). However, although early loosening of the cup in cemented low-friction arthroplasty is due to a poor bone stock on the acetabular side, late loosening is due to PE wear, particularly in young patients (Garcia-Cimbrelo and Munuera 1992).

Conventional PE wear is higher in uncemented cups. Some older designs such as the cylindrical PE liners were abandoned due to the higher rates of rupture (Garcia-Rey and Garcia-Cimbrelo 2007). Thus, the use of a 32-mm femoral head with conventional PE is no longer recommended due to the high wear rates and the appearance of liner ruptures (Hallan et al. 2006; Cruz-Pardos and García-Cimbrelo 2001; Cruz-Pardos et al. 2005; Garcia-Rey and Garcia-Cimbrelo 2008) (Fig. 9.2). On the contrary, the use of a 28-mm femoral head with a conventional PE liner in uncemented cups has shown lower rates (García Rey et al. 2009). When a threaded uncemented grit-blasted titanium cup is used, wear is also related to femoral head diameter (Garcia-Cimbrelo et al. 2003). Finally, nonmodular cups seem to produce less wear due to the absence of backside wear (Young et al. 2002); nevertheless this finding has not been confirmed by other authors (González Della Valle et al. 2004).

We can summarise that conventional PE wear depends on several factors related to the patient, such as physical activity, age or weight; to surgical technique, like the placement of the cup with a high acetabular abduction angle; and to the surgeon's choice to use a large head matched to a thin PE, or maybe a modular uncemented cup.

Other PEs different from gamma sterilised in air were developed in order to improve wear performance. Some of them were sterilised in nitrogen, plasma gas or argon. These types of PEs, however, did not improve the wear rates over gamma sterilised-in-air PEs. Recently, Engh et al. reported higher wear rates for one of these types of PEs, a wear that was related to larger osteolytic lesions (2012).

9.2 Highly Cross-Linked Polyethylenes

Reducing wear debris reduced the rate of osteolysis, this phenomenon being a combination of decreased PE wear resistance with loss of mechanical properties and increased oxidation (Gómez-Barrena et al. 2008). So-called first-generation

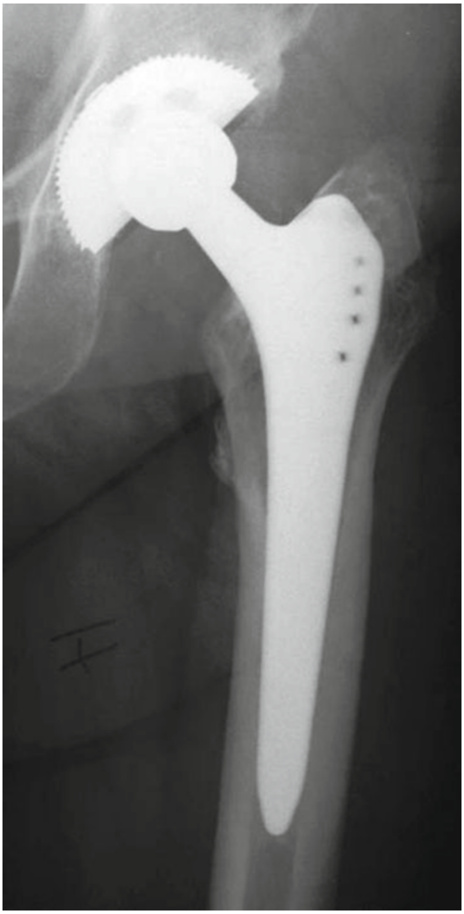

Fig. 9.3 Radiograph of a 64-year-old female patient with an uncemented THR using remelted HXLPE matched to a 28-mm femoral head with an excellent clinical result at 10 years of follow-up

highly cross-linked polyethylenes (HXLPE) attempt to achieve this, avoiding the production of free radicals and oxidation. All HXLPE are irradiated with high doses of gamma or electron beams, a thermal treatment to anneal or remelt the PE (trying to eliminate free radicals) and a sterilisation process in the absence of air. Increased cross-linking provides decreased HXLPE wear compared to conventional PE in vitro (McKellop et al. 1999; Muratoglu et al. 2001). The early first retrieval analyses of HXLPEs showed minimal wear and the reappearance of most of the machining marks after heat treatment, and although a higher inflammatory response has been reported, there was no evidence of particle disease in the histological study (Knahr et al. 2007; Illgen et al. 2008). During the last years other clinical reports have shown reduced wear when comparing HXLPE with conventional PEs; however, we still do not know the long-term results and if these improvements result in less osteolysis and loosening (García-Rey et al. 2008; Kuzyk et al. 2011) (Fig. 9.3).

But there are still some concerns regarding HXLPEs. The mechanical properties of melted HXLPEs may be affected due to the changes in the microstructure of the polymer that could decrease toughness and fatigue resistance. To date, the annealing process does not completely eliminate free radicals (Gómez-Barrena et al. 2008). For this reason, the so-called second-generation HXLPEs have been developed in recent years. The subsequent vitamin E diffusion instead of melting after the irradiation process avoids the loss of crystallinity observed in melted HXLPE, which is one of the sources of the decreased mechanical and fatigue strength (Oral et al. 2006). The other option is sequential annealing in order to improve the oxidation resistance and decrease the appearance of free radicals without compromising mechanical properties (Dumbleton et al. 2006).

9.3 Large Femoral Heads

The improvement of wear resistance observed with HXLPEs has renewed the interest in using 32-mm-diameter or even larger femoral heads in THR. In vitro examination of large 40-mm femoral heads showed improved wear resistance compared to conventional aged PE and a higher fatigue resistance (Burroughs et al. 2006). On the other hand, fracture of the superior rim of retrieved acetabular liners observed in first-generation HXLPEs with a ring-locking mechanism suggests that a thin liner and a vertical cup alignment could be the causes of this failure (Tower et al. 2007). In another hip simulator study, the mean wear rate for a 36-mm-diameter liner was slightly higher than the rate for 28-mm liners and tended to decrease with decreasing liner thickness; they also reported a tendency for contact stress to increase as the thickness of the liner decreased in a finite element modelling; and the authors concluded that with a proper orientation, the diameter of the ball could be increased (Shen et al. 2011).

The theoretical advantages of using large femoral heads in THR are due to the increased head and neck ratio that would decrease the appearance of impingement. An improvement in the range of motion and a higher displacement of the femoral head that produce dislocation using femoral heads with a diameter larger than 32 mm has been reported in vitro (Burroughs et al. 2005). On the other hand, Sariali et al. reported that the jumping distance for dislocation decreases as the abduction angle and the head offset increases, the latter more important when using large heads (2009). The biomechanics of large heads in THR has also been assessed in finite element models to evaluate the geometry and the anatomic orientation of the cup, and although increasing the diameter of the femoral head may improve hip stability, a vertical orientation of the cup does not provide the desirable effect and also produces a maximum stress area so the durability of the PE might be altered (Crowninshield et al. 2004).

Clinical studies report a decrease in the early dislocation rate using large femoral heads compared with a 28-mm femoral head; however, the problem of dislocation increases during the following years, and wear and liner ruptures have been related to the use of these large heads combined to HXLPEs (Howie et al. 2012). Thus, they were not able to reduce the prevalence of early dislocation after primary THR in high-risk patients compared to historical controls (Lachiewicz and Soileau 2006).

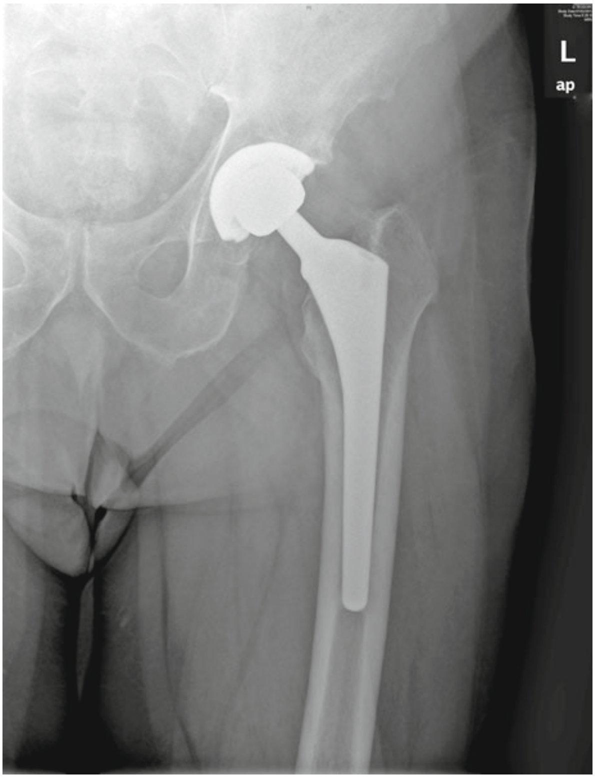

Fig. 9.4 Radiograph of a 68-year-old female patient with an uncemented THR and vitamin E-doped PE matched to a 32-mm femoral head with an excellent clinical result at 3 years of follow-up

It is well known that dislocation is a multifactorial problem and large heads have not reduced the rate of instability when the abductor mechanism is absent (Kung and Ries 2007). There is also a lack of studies comparing the use of a 32-mm femoral head to a 36 mm in so far as reducing the rate of dislocation is not confirmed (Fig. 9.4).

The other variables assessed in clinical practice have been wear and range of motion. Although similar linear wear has been reported when comparing large femoral heads and 28- or 32-mm femoral heads, volumetric wear was higher in a mid-term follow-up, so caution is recommended before using these implants, particularly in young patients and in those with a low risk for dislocation (Lachiewicz et al. 2009). Another study observed a similar higher volumetric wear; when range of motion was compared, equivalent results were found in contrast to in vitro studies and the risk of dislocation was not completely eliminated (Hammerberg et al. 2010). Some other clinical problems like pain due to psoas impingement when using large cup sizes have also been reported (Cobb et al. 2011).

The clinical evidence does not yet support the theoretical advantages of using femoral heads larger than 32 mm in THR combined to HXLPEs for now. The still valid concept of low-friction arthroplasty developed by Charnley must be considered before using these implants. The high-friction torque of large femoral heads in THR is a potential concern, and although there is a reduced rate of dislocation when using 36-mm femoral heads compared to 28-mm heads, the wear-related problems and the benefits of an increase in the range of motion are not substantially proven. The use of a 32-mm femoral head matched to HXLPEs can again be recommended, given the better mechanical properties of the latter, particularly in large cup sizes in primary THR.

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