

2.1

Introduction

Wear is the major reason of late failure of total hip arthroplasties [10, 14, 19] as the debris can lead to osteolysis and implant loosening [6–32]. Progressive osteolysis can produce loss of bone, implant failure, and difficulties in revision due to bone deficiency.

All the problems of wear, debris, and loosening arose first with polyethylene (PE). The best “treatment” is to prevent failures related to articulation by employing low wear bearing surfaces and monitoring the patients. As a matter of fact, the main problem is not the osteolysis by itself but the progression of osteolysis leading to major bone defects. This progression is not linear but can be exponential (Fig. 2.1), particularly in metal-backed cups due to a stress-shielding phenomenon that has been demonstrated in some studies which have evaluated the bone remodeling around press-fit cups [23, 26]. This area of bone reabsorption can be an easy way where osteolysis progresses. To avoid major damages, patients with joint arthroplasties should be monitored in periodical follow-ups both clinically and radiologically, and in case of progression of osteolysis, they should be revised early (Fig. 2.2). The monitoring of the patients is very important as a first radiological sign of osteolysis appears.

Anyway, the key point of prevention of failures remains the use of materials with high wear resistance. This is the reason justifying the employment of hard bearings in young patients and of new types of PE, thus reducing wear, but of course it is necessary not to increase other complications related to these materials. It is well known that every coupling has advantages but also its own disadvantages. Standard PE was associated with major wear and osteolysis, even if the problem mainly occurred as a consequence of the sterilization process. In fact, in many cases, the failures were due to the oxidation of PE related to gamma-radiation sterilization in air [21]. There is evidence in the literature [22], and we have personally the same experience, that standard PE, sterilized in ethylene oxide,

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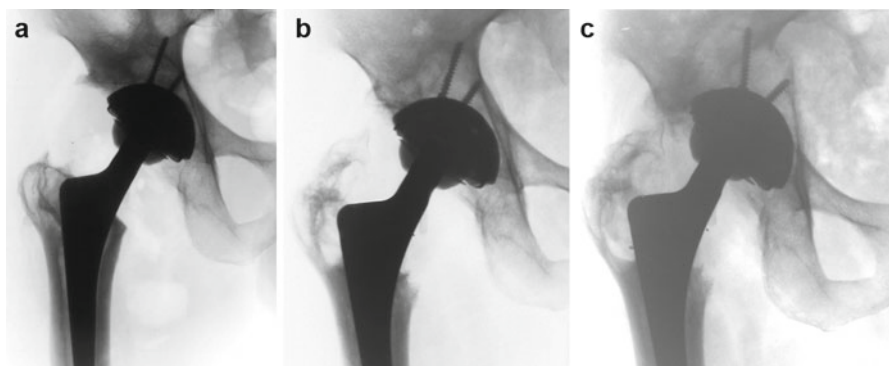


Fig. 2.1 (a) Male, 50 years old, ceramic 32-mm heads on standard PE showing progression of osteolysis. (b) Clear osteolysis and eccentricity of the head is already visible. (c) In 2 years catastrophic wear

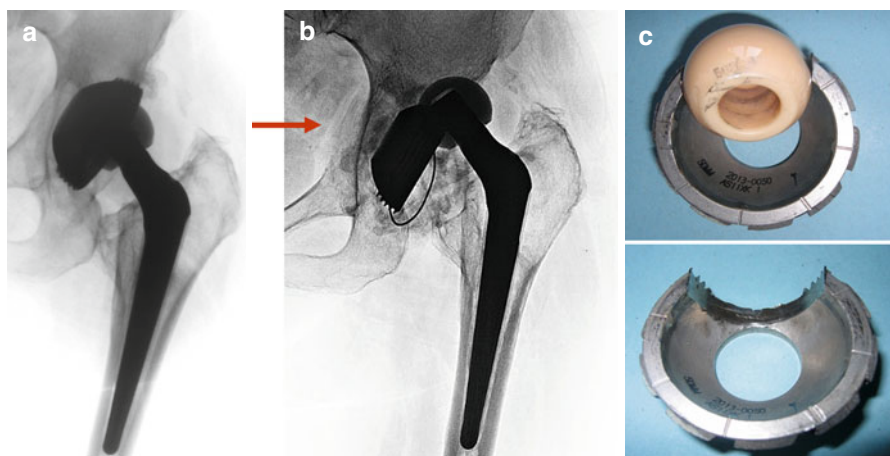


Fig. 2.2 (a) Female, 62 years old, 7 years postop ceramic 28-mm head on standard PE. The cup is vertical, the head is eccentric; revision was unfortunately not suggested. (b) Four years later, balloon sign and huge metallosis. (c) The ceramic head destroyed the liner and the metal back

shows excellent clinical long-term results. Cross-linked PE (X-PE) is associated with less wear, but the smaller particles produced could potentially be cause of major osteolysis. Breakage of the X-PE liners has been described especially in steep cups with elevated rims [11, 29]. Ceramic on ceramic is the tribology which has demonstrated the lowest wear rate both in experimental and in clinical studies. Moreover, ceramic is biologically inert, so it is the material with the highest biocompatibility, but breakage and noises can occur [1, 5, 15, 18]. Metal on metal has showed a very low wear, but a lot of tissue reactions have been described especially with the introduction of big metal heads. The so-called ARMD (Adverse Reaction to Metal Debris) includes several metal-on-metal effects: ALVAL

(Aseptic Lymphocyte Dominated Vasculitis Associated Lesions), high ion blood levels, osteolysis, and pseudotumors, and it is a reason of major concern nowadays [3, 4, 24, 31], even if authors have showed good clinical results [7, 27].

Each material with its own properties has its own advantages and disadvantages, and every implant can fail for tribology reasons. The question is: what to do in case of failure? The answer to this question has the aim of helping the orthopedic surgeon in the decision making in case of hip revision, giving some practical suggestions for everyday practice.

2.2

Revision Options

The key points for treatment in case of failure that must be considered are:

- To identify the origin of the problem in order to avoid to repeat the failure
 - To verify the implant stability
 - To evaluate if there is any malposition of the components (particularly relevant is the orientation of the cup)
 - To optimize the coupling to reduce wear
 - To restore, when possible, the anatomy of the hip (the center of rotation and the offset and the bone stock)
 - To treat in the best way the soft tissue damages
 - To treat and to avoid any impingement
- Surgical options are:
- Liner and/or head exchange in a stable implant
 - Revision of the cup of the stem of both

The aim is to move toward a coupling with a lower wear with a surgery less invasive as possible.

On this way, out of the infected cases, there are different decision-making factors that must be considered:

- Implant stability: if one of the components is not stable, of course, it must be revised, but sometimes in case of tribology failures, the surgeon has also to replace stable implants which do not work properly or are damaged. Techniques and instrumentations for implant removal should be available in the operating room.
- Position of the components: if there is a clear malposition, the replacement of the liner is not enough and the component must be reimplanted in a correct position. The cup orientation remains “crucial”. Vertical or worse both vertical and anteverted cups have to be revised. This cup position can lead to edge loading which causes stripe wear and eventually massive wear also with hard bearings. Malposition can be also the reason of impingement between the neck of the stem and the rim of the cup which is a cause of metal wear, but it is also the mechanism of fracture of the ceramic liner [5, 25]. Also microseparation can lead to rapid wear; insufficient tension of abductors muscles or lack of offset can be the causes [16].
- Implant modularity and availability of the components: in the preoperative planning, the information regarding the prosthesis that has to be revised should be known. Implants of any possible useful standard of all the parts should be available in the operating room at the time of the operation.

- Damage of the components: if there are major damages of the cup or of the stem at the level of the locking mechanism, they have to be revised even if stable. A ceramic liner cannot be used in a bore of the metal back, thus avoiding a fracture. In these cases, the only salvage procedure can be to cement a PE liner inside the metal back in older patients [13]. A ceramic head, even if of the revision type, but also a metal head cannot be employed if there is a gross damage of the adaptor cone and the stem has to be removed.
- Bone stock: the restoration of the bone stock is part of the revision surgery and can, of course, enhance the life of the prosthesis. There are different techniques both in the acetabular and in the femoral side that the surgeon has to know.

Revising the different types of coupling, the surgeon can choose among several options, and there are various suggestions for the tribology of the new implant.

2.2.1

Revision of PE

It is better to employ X-PE liners or ceramic-on-ceramic coupling in the younger patients, paying attention in avoiding malpositioning. Standard PE “correctly” sterilized can be employed in older patients. In less active patients with stable cups, it can be simpler and bone preserving to cement a liner or better a PE cup in the metal back [13]. In this case, it is advisable to remove the screws or the plugs, when present, and to drill in the holes of the cup in order to improve the locking mechanism of the cement. Then, the metal back should be accurately dried. When a liner is employed instead of a PE cup, it can be scratched if the back is too smooth, and antibiotic-loaded cement is suggested. The head should be changed if possible, especially in case of metal head. The exchange is mandatory in case of damage of the head. If there are no major damages of the adaptor cone, revision ceramic heads or metal heads should be used. Bone graft should be employed in case of acetabular and femoral defects.

If the cup and the stem are stable and in correct position and the liner and the head are modular and available, the replacement of the liner and of the head is enough, improving the tribology if possible.

If the cup and/or the stem are not stable, they obviously should be revised. X-PE or ceramic-on-ceramic are suggested as bearing surfaces. Bone graft, revision technique, and eventually revision implant may be necessary.

If the cup and the stem are stable but malpositioned or there is no possibility of improving the tribology in younger patients, they should be revised: at least the cup together with the head exchange. It is rarely necessary in this case to revise both. The stem has to be changed alone if severely damaged and/or monoblock (without modular head or neck). Cemented stems can be recemented [17, 33] with the cement-within-cement technique in older patients. All the difficulties linked to the removal of a cemented or uncemented stable stem can occur.

If the cup and the stem are stable and correctly oriented but damaged or nonmodular, they must be revised, improving the tribology. Cup and stem removal and revision techniques are necessary again. In older patients a new liner can be cemented in the stable metal back.

2.2.2

Revision of Metal on Metal

It can be advisable to employ ceramic on X-PE or ceramic on ceramic in the younger patients, again paying attention to malpositioning. Moreover, every metal is different from the other, and they cannot absolutely be mixed from one company to the other. Of course, in case of clear adverse reactions to metal debris, a further metal tribology should be avoided particularly in case of suspected allergy. The surgery procedure has to be aggressive in these cases, removing as much inflammatory soft tissues and metallosis as possible. Otherwise, poor outcome has been described [9].

If the stem is stable, the cup is revised and the head is exchanged, better with a ceramic on X-PE or ceramic on ceramic in young patients in addition to the soft tissue treatment.

If the stem is not stable or damaged, it has to be revised of course, together with the cup, moving to X-PE or ceramic in case of doubt of ARMD. Again, soft tissue aggressive treatment and revision techniques may be necessary.

In case of problems linked to resurfacing such as neck fracture, a conversion to a total hip arthroplasty is usually performed with large metal heads [2]. It is possible when the cup is stable, well oriented and not damaged, and with no signs of ARMD.

2.2.3

Revision of Ceramic on Ceramic

In case of aseptic loosening of ceramic on ceramic, X-PE or ceramic can be employed again in young patients. If the ceramic is certainly not broken also metal heads can be used.

If the cup is not stable it is revised and a revision ceramic head or a metal head is employed on the stable stem.

In a stable cup, a new ceramic liner can be employed if there is the absolute certainty that the metal back is not damaged and if it is correctly positioned. Otherwise, a PE liner is advisable or a revision of the cup should be performed. This same concept is applied in case of squeaking even if moving to a different coupling (X-PE on metal or X-PE on ceramic) is suggested to avoid the risk of recurrence.

The main problem with ceramic is in case of breakage, which nowadays can happen mostly to the liner [30]. With hard bearings, orientation is crucial, and ceramic bearing, such as in case of metal on metal, is not forgiving. The mechanics of fracture [5] shows that poor coverage, as it occurs in vertical and anteverted cups, causes edge loading in the upper part of the liner and neck impingement in the inferior rim of the cup. Neck impingement leads to subdislocation and to consequent very small contact on the upper rim, provoking ceramic grain detachment with third body wear and crack propagation with ceramic breakage. Not only the orientation but also the screws can be risky in case of protrusion in the metal back [15]. This is the reason why, with stable press-fit cups, it is suggested to avoid the use of additional screws if not strictly necessary. Moreover, ceramic must be handled with care: any damage of the metal back in the acetabular side and of the adaptor cone of the stem must be avoided. During the liner insertion, attention has to be paid in avoiding

jamming of the liner in a wrong position. All these even small defects can lead to a ceramic breakage.

In case of breakage, an urgent revision must be performed (it is an emergency!) as to avoid the progression of damages. All the visible fragments have to be removed; the soft tissue debridement must be “aggressive” (of the capsule, of the bursa, etc.), adding plenty of washing out. If there is a major damage of the metal back or the cup is malpositioned, it must be revised. If there is a real major damage of the cone of the stem, it must be revised too. In case of minor damage of a well-oriented metal back, a PE liner suitable for the cup can be employed and a revision ceramic head should be employed. Some Authors [28] have reported good results with very aggressive soft tissue removal and metal-on-PE employment, but also catastrophic results have been described as a consequence of massive wear and metallosis of the metal head [8, 20]. Ceramic on ceramic has been suggested in such cases [12, 30]. Even a minimal damage of the shell cannot be tolerated inserting a new ceramic liner. In this situation a revision of the cup is mandatory. Moreover, small residual ceramic fragments can act as third body. PE on ceramic could be the best option or at least the less worse, as in this case the small ceramic fragments are pushed and embedded into the PE liner and the abrasion of the ceramic head is minimal.

2.3

Conclusion

Troubles with materials of THA teaches that there is not an ideal solution for every case in tribology and that the surgeon must select the proper indication for each patient considering age, level of activity, bone quality, local anatomy, and risk factors.

The correct component position and orientation is critical for each coupling, but for hard bearings, it is less forgiving. This means that, out of the choice of the materials, a proper surgical technique and implant position remain crucial. The correct orientation can be a reason of concern for using approaches or surgical techniques that can be at risk of more difficult positioning such as minimal invasive surgery. From this point of view, the surgeon must take an overall view of pros and cons when introducing new techniques and new materials.

Patients need periodical X-rays and clinical evaluation. Monitoring of the cases is an advantage for the clinical outcome of the patient that can be revised early, thus preventing progression of osteolysis, worsening of tribology problems, and major bone defects. But it is also an advantage for the health systems, thus avoiding further more complicated revisions with more expensive devices, more expensive hospitalization, and expensive bone allografts. The surgeon has to take care on the standard X-rays of the appearance and particularly of the progression of osteolysis; of the head position, which should be not eccentric; and of the state of the components. In case of doubt, the CT scan can be helpful for evaluating the integrity of the components of the prosthesis and the position of the head (Fig. 2.3). In rare cases, MR or US for studying soft tissue reactions around the implant can be indicated. The clinical appearance of new noises coming from the articulation is anyway a reason of major concern and must be carefully investigated.

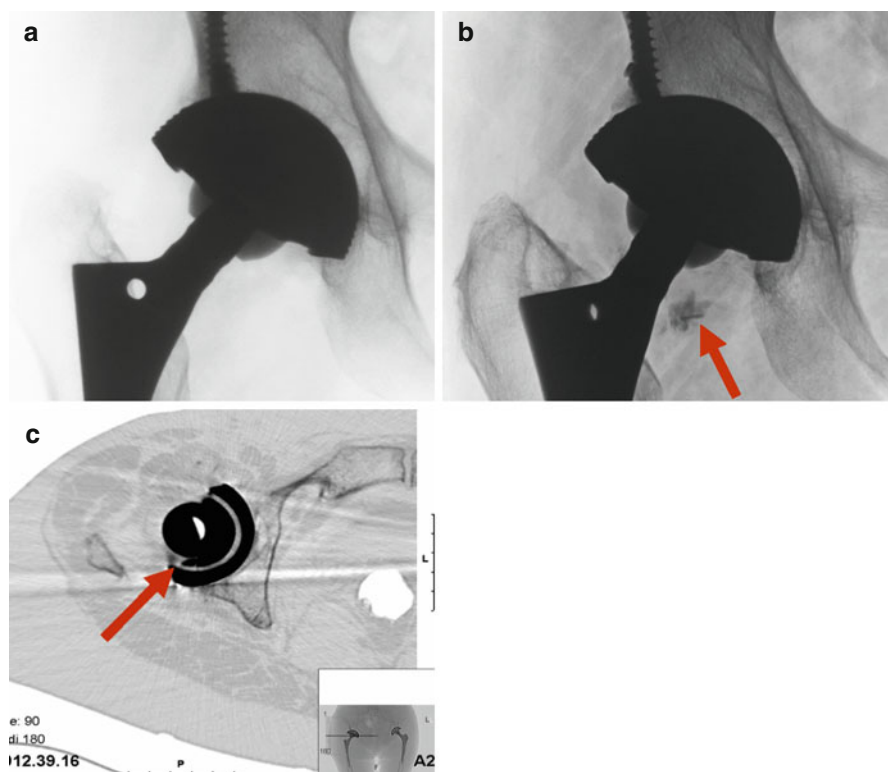


Fig. 2.3 (a) Female, 58 years old, ceramic-on-ceramic coupling with an old sandwich PE liner. (b) Twelve years later, appearance in the X-ray of a new radiological sign suspected for ceramic breakage. (c) CT scan confirms the breakage. The *red arrows* indicate ceramic fragments

Early revision improving the tribology can prevent catastrophic complications such as loosening or bone loss. It should be considered also in asymptomatic, healthy, and active patients in case of progression of wear and of osteolysis. In these cases, the surgeon should balance advantages and disadvantages of further surgeries avoiding ineffective waiting but also too much aggressive treatments.

During the revision, well-fixed implants should be maintained and revised only if strictly necessary such as in case of damaged or malpositioned nonmodular components. The proper tribology should be chosen depending on the patient. Hard low wear-bearing surfaces are indicated for younger and active patients, but also for patients that have shown subjective tendency toward major osteolytic reaction with the previous implant [32]. In any case, the surgeon should not faith only on tribology, but first of all in the surgical technique avoiding malposition and impingement, which are two of the main causes of implant failure. Moreover, during revision surgery, the anatomy (mainly center of rotation and offset) and bone stock should be restored when possible. Any malposition that can have a clinical or tribology effect should be corrected and the implant revised. In very severe cases, when risks of instability or of impingement linked to the difficulty of reconstructive

surgery still persist, hard bearings should be employed carefully in order to avoid a failure related to the materials.

References

1. Allain J, Roudot-Thoraval F, Delecrin J, Anract P, Migaud H, Goutallier D (2003) Revision total hip arthroplasty performed after fracture of a ceramic femoral head. A multicenter survivorship study. *J Bone Joint Surg Am* 85-A(5):825–830
2. Ball ST, Le Duff MJ, Amstutz HC (2007) Early results of conversion of a failed femoral component in hip resurfacing arthroplasty. *J Bone Joint Surg Am* 89(4):735–741
3. Browne JA, Bechtold CD, Berry DJ, Hanssen AD, Lewallen DG (2010) Failed metal-on-metal hip arthroplasties: a spectrum of clinical presentations and operative findings. *Clin Orthop Relat Res* 468(9):2313–2320
4. Clayton RA, Beggs I, Salter DM, Grant MH, Patton JT, Porter DE (2008) Inflammatory pseudotumor associated with femoral nerve palsy following metal-on-metal resurfacing of the hip. *J Bone Joint Surg Am* 90(9):1988–1993
5. Dalla Pria P, Zagra L, Esopi P, Masoni D (2010) Breakage and noises in ceramic on ceramic couplings. *Eur Orthop Traumatol* 1:53–59
6. Emms NW, Stockley I, Hamer AJ, Wilkinson JM (2010) Long-term outcome of a cementless, hemispherical, press-fit acetabular component: survivorship analysis and dose–response relationship to linear polyethylene wear. *J Bone Joint Surg Br* 92(6):856–861
7. Girard J, Bocquet D, Autissier G, Fouilleron N, Fron D, Migaud H (2010) Metal-on-metal hip arthroplasty in patients thirty years of age or younger. *J Bone Joint Surg Am* 92(14):2419–2426
8. Gozzini GA, Schmid C, Dalla Pria P (2002) Massive wear in CoCrMo head following the fracture of an alumina head. *Hip Int* 12:37–42
9. Grammatopoulos G, Pandit H, Kwon Y-M, Gundle R, McLardy-Smith P, Beard DJ, Murray DW, Gill HS (2009) Hip resurfacings revised for inflammatory pseudotumor have a poor outcome. *J Bone Joint Surg Br* 91-B:1019–1024
10. Huo MH, Brown BS (2003) What's new in hip arthroplasty. *J Bone Joint Surg Am* 85-A(9):1852–1864
11. Jacobs CA, Christensen CP, Greenwald AS, McKellop H (2007) Clinical performance of highly cross-linked polyethylenes in total hip arthroplasty. *J Bone Joint Surg Am* 89(12):2779–2786
12. Kempf I, Semlitsch M (1990) Massive wear of a steel ball head by ceramic fragments in the polyethylene acetabular cup after revision of a total hip prosthesis with fractured ceramic ball. *Arch Orthop Trauma Surg* 109(5):284–287
13. Khanuja HS, Aggarwal A, Hungerford MW, Hungerford DS, Jones LC, Mont MA (2010) Cementing polyethylene liners into non-modular acetabular components in revision total hip arthroplasty. *J Orthop Surg* 18(2):184–188
14. Learmonth ID (2003) Biocompatibility: a biomechanical and biological concept in total hip replacement. *Surgeon* 1(1):1–8
15. Lee SC, Jung KA, Nam CH, Kim TH, Ahn NK, Hwang SH (2010) Acetabular screw head-induced ceramic acetabular liner fracture in cementless ceramic-on-ceramic total hip arthroplasty. *Orthopedics* 33(5). doi:10.3928/01477447-20100329-30
16. Leslie IJ, Williams S, Isaac G, Ingham E, Fisher J (2009) High cup angle and microseparation increase the wear of hip surface replacements. *Clin Orthop Relat Res* 467(9):2259–2265
17. Lieberman JR, Moeckel BH, Evans BG, Salvati EA, Ranawat CS (1993) Cement-within-cement revision hip arthroplasty. *J Bone Joint Surg* 75 B:869–871
18. Lusty PJ, Watson A, Tuke MA, Walter WL, Walter WK, Zicat B (2007) Wear and acetabular component orientation in third generation alumina-on-alumina ceramic bearings: an analysis of 33 retrievals [corrected]. *J Bone Joint Surg Br* 89(9):1158–1164

19. Mäkelä KT, Eskelinen A, Pulkkinen P, Paavolainen P, Remes V (2011) Results of 3,668 primary total hip replacements for primary osteoarthritis in patients under the age of 55 years. *Acta Orthop* 82(5):521–529
20. Matziolis G, Perka C, Disch A (2003) Massive metallosis after revision of a fractured ceramic head onto a metal head. *Arch Orthop Trauma Surg* 123(1):48–50
21. McKellop HA, Campbell P, Park SH, Schmalzried TP, Grigoris P, Amstutz HC, Sarmiento A (1995) The origin of submicron polyethylene wear debris in total hip arthroplasty. *Clin Orthop Relat Res* 311:3–20
22. McKellop HA, Shen FW, Lu B, Campbell P, Salovey R (2000) Effect of sterilization method and other modifications on the wear resistance of acetabular cups made of ultra-high molecular weight polyethylene. A hip-simulator study. *J Bone Joint Surg Am* 82-A(12):1708–1725
23. Mueller LA, Voelk M, Kress A, Pitto RP, Schmidt R (2007) An ABJS best paper: progressive cancellous and cortical bone remodeling after press-fit cup fixation: a 3-year followup. *Clin Orthop Relat Res* 463:213–220
24. Murray DW, Grammatopoulos G, Gundle R, Gibbons CL, Whitwell D, Taylor A, Glyn-Jones S, Pandit HG, Ostlere S, Gill HS, Athanasou N, McLardy-Smith P (2011) Hip resurfacing and pseudotumour. *Hip Int* 21(3):279–283
25. Onda K, Nagoya S, Kaya M, Yamashita T (2008) Cup-neck impingement due to the malposition of the implant as a possible mechanism for metallosis in metal-on-metal total hip arthroplasty. *Orthopedics* 31(4):396
26. Pitto RP, Bhargava A, Pandit S, Walker C, Munro JT (2008) Quantitative CT-assisted osteodensitometry of femoral adaptive bone remodelling after uncemented total hip arthroplasty. *Int Orthop* 32(5):589–595
27. Saito S, Ishii T, Mori S, Hosaka K, Ootaki M, Tokuhashi Y (2010) Long-term results of metal-on-metal total hip arthroplasty. *Orthopedics* 11;3(8):3
28. Sharma V, Ranawat AS, Rasquinha VJ, Weiskopf J, Howard H, Ranawat CS (2010) Revision total hip arthroplasty for ceramic head fracture: a long-term follow-up. *J Arthroplasty* 25(3):342–347
29. Tower SS, Currier JH, Currier BH, Lyford KA, Van Citters DW, Mayor MB (2007) Rim cracking of the cross-linked longevity polyethylene acetabular liner after total hip arthroplasty. *J Bone Joint Surg Am* 89(10):2212–2217
30. Traina F, Tassinari E, De Fine M, Bordini B, Toni A (2011) Revision of a ceramic hip for fractured ceramic components. *J Bone Joint Surg Am* 93(24):1471–1479.
31. Willert HG (2005) Metal-on-metal bearings and hypersensitivity in patients with artificial hip joints. A clinical and histomorphological study. *J Bone Joint Surg Am* 87(1):28–36
32. Willert HG, Bertram H, Buchhorn GH (1990) Osteolysis in alloarthroplasty of the hip. The role of ultra-high molecular weight polyethylene wear particles. *Clin Orthop Relat Res* 258:95–107
33. Young J, Vallamshetla VR, Lawrence T (2008) The polished tri-tapered stem for cement-in-cement revision hip arthroplasty, a reliable and reproducible technique? *Hip Int* 18(4):272–277

Total Hip Arthroplasty

Wear Behaviour of Different Articulations

Knahr, K. (Ed.)

2012, VIII, 187 p. 79 illus., 57 illus. in color., Softcover

ISBN: 978-3-642-27360-5