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REVIEW

Strategies for head and inlay exchange in revision hip arthroplasty

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Abstract Due to the increasing number of total hip arthroplasties performed during the last three decades and the limited long-term survival, mainly because of wear, the number of revisions has increased during the last two years. If the implant itself is still considered to be stable, only head and inlay exchange is necessary. This requires comprehensive knowledge of the characteristics of the articulating materials by the surgeon as the wrong choice of wear couple can lead to early failure for a second time. The aim of this paper is to present considerations and strategies for head and inlay exchange in case of failure, either due to wear of the articulation material or of other indications for revision hip arthroplasty.

Introduction

During the last two years revision surgery has become more and more important because of the increased number of total hip arthroplasties performed during the past three decades and their limited long-term survival mainly due to polyethylene wear [1]. To avoid osteolysis and subsequent loosening of the implant [2], several attempts have been made to improve the wear characteristics of the bearing surfaces. On the one hand, conventional polyethylene has been improved by cross-linking, and on the other hand metal-on-metal and ceramic-on-ceramic articulations have been introduced [3–6]. Despite the dramatically reduced wear rate of all these new articulations orthopaedic surgeons are still faced with problems related to each single combination [7, 8]. The exact knowledge of the characteristics of the materials being used in case of revision is necessary to avoid an early re-failure.

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Strategies for metal/ceramic-on-polyethylene articulations

The major reason for revision of these couplings is increased polyethylene wear which leads to subsequent osteolysis (Fig. 1). As the annual wear rate of metal-on-polyethylene is approx. 0.1–0.3 mm/y and the rate for ceramic-on-polyethylene is about 0.05–0.15 mm/y [9], the onset of visible wear and osteolysis occurs later in ceramic articulations than in metal articulations [10].

In case of revision there are almost no limitations to the use of subsequent implant materials for revision surgery, as the only debris material found is polyethylene with insignificant amounts of metal or ceramic particles. The only limitation is visible damage to the surface structure of the taper of a stable stem that can occur during rough removal of the head. If an alumina ceramic head were to be used on a damaged taper, high stress concentration could develop leading to a breakage of the ball. In the past this fact meant that an exchange of the stem was necessary if the surgeon wanted to use a ceramic head again. To solve this problem, new concepts have been developed over the last couple of years. Special revision ball heads made of an alumina composite ceramic with a metal sleeve designed to reduce the effect of stem taper unevenness on the reliability of the ball head were developed [11]. This combination offers new possibilities for the use of ceramic heads in revision total hip arthroplasty. The titanium sleeve adapts to the taper of the stem which creates a smooth taper surface where the new ceramic head is fitted. Possible neck lengths

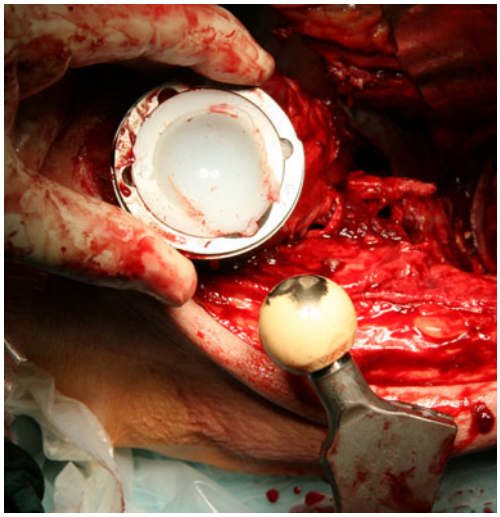

Fig. 1 Extensive wear due to impingement (ceramic-on-polyethylene)

are S, M, L and also XL which are achieved through different metal sleeves. Compared to XL metal heads the revision ceramic ball heads are not skirted to achieve an extended range of motion without impingement between the prosthetic neck and the cup.

Strategies for revision of metal-on-metal articulations

Metal-on-metal articulations were reintroduced by Weber in 1988 as an alternative to metal/ceramic-on-polyethylene bearings in the light of the improved wear behaviour of high carbon implants. As a result a renaissance of this material combination for articulating surfaces in total hip arthroplasty began. Compared to ceramic-on-polyethylene and metal-on-polyethylene articulations, the annual wear rate is much lower (approx. 0.01 mm/y) [12]. In addition, the metal particles are smaller than polyethylene particles and may therefore induce less tissue reaction.

However, there are several reports in literature that show some disadvantages of using metal-on-metal articulations. The serum levels of cobalt and chromium ions were significantly higher in patients with a metal-on-metal bearing compared to patients with other bearings [13, 14]. The blood levels of metal ions can accumulate and achieve very high values, especially in patients with renal insufficiency [15]. Nevertheless, these values were far below the limits of cytotoxicity [16]. Metallic wear can also reach high levels when there is impingement of the femoral and acetabular component due to incorrect implantation. The typical intraoperative finding is blackening of the synovia called metallosis.

The released ions can form metal-protein complexes that are considered to act as antigens and to activate the immune system leading to a hypersensitivity response [17]. This reaction can lead to early osteolysis and aseptic loosening of components (Fig. 2) [18–21]. Clinical data suggest an association with a delayed hypersensitivity type IV to metal, mainly cobalt. It is still unclear whether the allergy to metal alloys exists preoperatively or the patients became hypersensitive secondary to metal particles. As a consequence, in patients with postoperative persisting or early recurrent, load-dependent thigh pain—with or without radiographic signs of osteolytic lesions—a possible hypersensitivity to metal should be considered.

All these problems from metal-on-metal articulations can be the reason for revision surgery. If impingement is identified as the reason for increased metallic wear, correct replacement of the components is mandatory. In all other cases a biological adverse reaction to metallic wear debris has to be considered and an exchange of the bearing partners is sufficient. This may be done by a total exchange of the metal-on-metal articulation using either a ceramic-on-ceramic or a ceramic-on-crosslinked polyethylene bearing.

Strategies for revision of ceramic-on-ceramic articulations

Alumina ceramic is a very hard and resistant material with excellent wear characteristics. The linear wear rate is very low and described in literature to be about 0.003 mm/year [22]. Nevertheless the elasticity of the material is also low and does not allow any deformation under load. High focal stress can lead to fracture either of the ceramic head or the ceramic liner. Correct attachment of the ceramic ball head is mandatory to prevent possible fracture. Exact positioning of the cup is necessary to avoid edge loading by impingement at the rim of the liner [23].

Due to these special characteristics, revisions are mainly not caused by osteolysis or secondary loosening of the

Fig. 2 Early osteolysis due to hypersensitivity to metal three years postoperatively

implant. The most serious problems of ceramics are fracture due to impingement or recurrent dislocation. Ceramic particles produced by fracture or wear may cause excessive wear on metal ball heads in metal-on-metal or metal-on-polyethylene bearings as these particles are much harder than metal. They lead to severe damage of all metal components in a very short time (= third body wear). For this reason only ceramic-on-ceramic or ceramic-on-(cross-linked) polyethylene bearings are recommended. The revision of ceramic components is not as straightforward as that of the other bearing partners and therefore requires a different approach to management.

Revision of the femoral head

Loose cup – stable stem

In many cases it is necessary to remove the ceramic ball head of a well fixed stem either to improve the exposure or to vary the length of the neck after cup revision. It is recommended to exchange the cup with the original ball head in place as long as possible to protect the taper. A rough removal can damage the surface structure of the taper. If a ceramic head were to be used on a damaged taper once again, stress concentrations can develop on the roughened surface of the taper that would lead to an increased risk of breakage. For this reason the removal should be done with special tools and under protection of a swab to avoid any scratches on the taper. In principle, if the surface structure is macroscopically not damaged a new ceramic head can be used. Only the surgeon can take responsibility when re-using the taper of a stable stem. Manufacturers state that tapers are never to be re-used with a ceramic ball head because of the danger of damage to the taper during removal which is not under their control. If the surgeon is uncertain or unwilling to take responsibility, he must remove the stem which often complicates the surgical procedure. The better option is to use the recently introduced ceramic revision ball head systems, a combination of a special toughened dispersion ceramic made of alumina and zirconia with a titanium sleeve that can be fitted on the original taper to create a smooth surface where a new ceramic ball head can be attached.

Stable implants – recurrent dislocation

One reason for recurrent dislocations may be abductor muscle weakness because of reduced tension of the muscle. This problem can be solved just by an exchange of the femoral head using a longer neck size. Again one is faced with the possible damage of the taper during removal of the original head. This can be solved either by careful removal described above or by using the ceramic revision ball heads with an inner metal sleeve. Since the introduction of the revision head system femoral neck lengths can be extended up to size XL (Fig. 3a, b).

Revision of fractured ceramic implants

Fracture of the ceramic head

Despite the substantial improvement in clinical performance the possibility of fracture continues. Most ceramic head fractures are caused either by a substantial trauma to the patient, or they are related to dislocation or to inadequate intraoperative handling when fixing the ceramic head on the metallic taper. With improved material and production technique the incidence of ceramic head fracture has decreased dramatically since 1990 and is nowadays a rare occurrence (0.015–0.004%) [24]. Today's alumina ceramics are more forgiving due to a reduced level of inclusions and a lower grain size and have therefore a much higher density level than former ceramics. There has also been an improvement in the production of a smoother surface of the taper to allow an optimal load transfer to the ceramic head and to avoid local stress concentrations in the metal-to-ceramic interface.

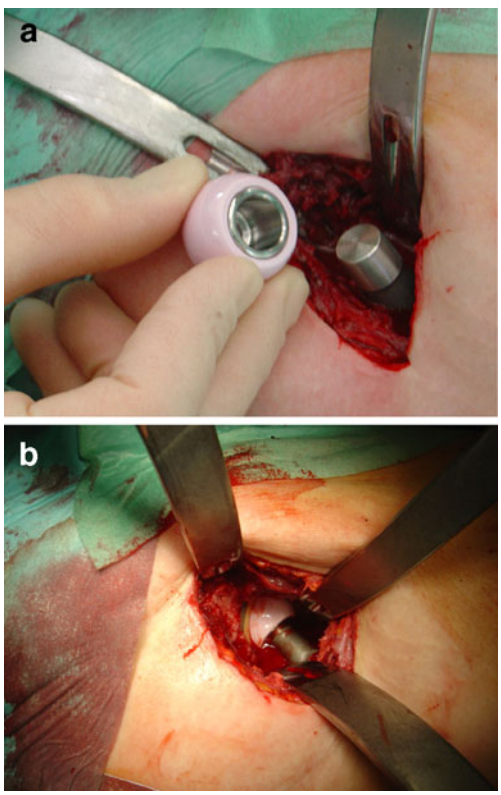

Fig. 3 **a**, **b** Revision ball head system by CeramTec. Inner metal sleeves allow ceramic XL neck sizes

In the rare case of head fracture many ceramic particles of different sizes can be found during revision. Despite meticulous synovectomy and extensive joint lavage there are always small particles left. This remaining debris is harder than metal and leads to third-body wear. Therefore it is absolutely essential to avoid an exchange to a metal head after fracture of a ceramic articulation. Especially if a polyethylene liner is used the small ceramic wear particles are forced into the soft polyethylene, which resembles sandpaper, leading to massive abrasion of the metal head [25]. The one and only choice of articulation type for revision is renewal of a ceramic wear couple to reduce the risk of third-body wear. Again, if the stem is intraoperatively considered stable and the taper is damaged, a ceramic revision ball head system with an inner metal sleeve should be used.

Fracture of the liner

Fracture of the liner can be caused either by intraoperative rim chipping due to malinsertion by the surgeon or by impingement between the rim of the liner and the femoral neck, especially in the early years when skirted balls were used. The incidence of fracture of ceramic inserts has been reduced in modern systems because nowadays the technique of assembly is better understood by the surgeons due to better training. Additionally, improved instruments allow correct insertion of the ceramic liner into the metal cup. Nowadays, fracture of the ceramic liner is a rare phenomenon [26, 27]. The incidence of rim chipping is reported to be about 0.008% (CeramTec Symposium 2005).

As in the revision of the femoral ceramic head it is important to remove the ceramic liner without damage to the inner surface of the cup. This is usually managed by a perpendicular impact to the rim of the metal shell of the cup resulting in a loosening of the conical press fit. With the use of a suction cup instrument the ceramic liner can be removed easily without any damage of the inner surface. Again, the one and only choice of articulation type is renewal of a ceramic wear couple to reduce the risk of third-body wear.

Prevention of ceramic failure

To avoid any damage to the ceramic liner during insertion a special suction cup instrument was created [28]. This allows a simple and secure manipulation of the liner in the titanium shell and can also be used to easily remove the liner in case of revision (Fig. 4a, b). It is important to align the ceramic liner into the exact final position into the cup. After verification of the proper position without impingement of soft tissues, one single soft blow with the impactor will fix the liner.

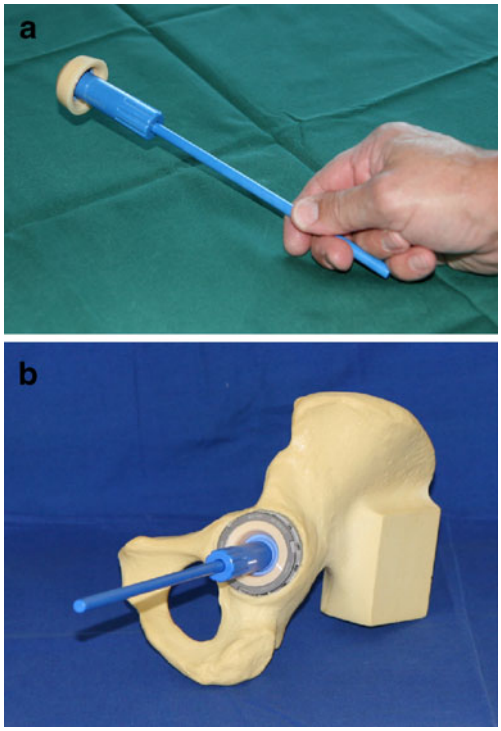

Fig. 4 **a**, **b** The suction cup instrument

With regard to the fixation of the ceramic ball to the taper, similar precautions should be taken. The ceramic head should be placed on the taper with a rotating movement to achieve primary fixation. The surface should be clean and dry. Any soft tissue between the head and the taper could lead to breakage during impaction. Only a single soft blow with the impactor should be added for complete stability.

Conclusion

Revision of a total hip arthroplasty needs comprehensive knowledge of the characteristics of the articulating materials. A wrong choice of wear couple can lead to early failure for a second time.

Selection of articulation in primary THA can be influenced by possible revision scenarios. Today the metal/ceramic-on-crosslinked polyethylene, metal-on-metal and ceramic-on-ceramic articulations offer excellent wear characteristics. As far as wear is concerned, ceramic-on-ceramic seems to be the optimal solution. Nevertheless, a certain risk for fractures exists and special guidelines for implantation and revision must be considered. During the last couple of years the revision of ceramic components became much easier due to the latest developments of special revision ball head systems consisting of a toughened dispersion ceramic combined with a metal sleeve.

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