Advantages and disadvantages of ceramic on ceramic total hip arthroplasty: A review

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Background. Ceramic on ceramic (COC) total hip arthroplasty (THA) was developed to reduce wear debris and accordingly, the occurrence of osteolysis and aseptic loosening especially in younger patients. Based on the excellent tribological behavior of current COC bearings and the relatively low biological activity of ceramic particles, significant improvement in survivorship of these implants is expected.

Methods. We used manual search to identify all relevant studies reporting clinical data on COC THAs in PubMed. The objective was to determine whether current COC THA offers a better clinical outcome and survivorship than non-COC THA.

Results. Studies with early generation ceramic bearings yielded 68% to 84% mean survivorship at 20 years follow-up which is comparable with the survivorship of non-COC THAs. Studies on current ceramic bearings report a 10-year revision-free interval of 92% to 99%. These outcomes are comparable to the survivorship of the best non-COC THAs. However, there are still concerns regarding fracture of sandwich ceramic liners, squeaking, and impingement of the femoral neck on the rim of the ceramic liner leading to chipping, especially in younger and physically active patients.

Conclusion. Current COC THA leads to equivalent but not improved survivorship at 10 years follow-up in comparison to the best non-COC THA. Based on this review, we recommend that surgeons weigh the potential advantages and disadvantages of current COC THA in comparison to other bearing surfaces when considering young very active patients who are candidates for THA.

Key words: total hip arthroplasty, ceramic on ceramic, revision free interval, survivorship, advantages, disadvantages, osteolysis, aseptic loosening

Received: November 22, 2011; Accepted: June 13, 2012; Available online: September 30, 2012

http://dx.doi.org/10.5507/bp.2012.063

INTRODUCTION

Particle-induced periprosthetic osteolysis and aseptic loosening are major complications of total hip arthroplasty (THA). The current paradigm relates osteolysis and loosening of THA to the cellular host adverse reaction due to continuous particle delivery from artificial joint surfaces. As osteolysis is closely associated with the production of large quantities of polyethylene (PE) particles, one solution would be to exclude PE from bearing materials used in THA and replace it by much harder and wear-resistant materials. The history of the use of ceramic materials, their structures, and the clinical outcomes of THAs with ceramic-on-ceramic (COC) bearings are described in detail elsewhere.

Here, we focus on the current ceramic materials that are used in orthopaedic practice today. These are formed by fusion of microscopic grains of alumina (Al₂O₃) and/or zirconia (ZrO₂) ceramic powder into a solid phase (Table 1). The process of sintering is “hot isostatic pressing” requiring temperatures exceeding 1400 °C and pressures above 1000 Bars. After sintering, the components are ground and polished to get the finest surface possible.

The manufacturing of COC bearings for orthopaedics is under strict control (more than 50 checkpoints according to the declaration of CeramTech AG, Plochingen, Germany) and in accordance with international quality standards (ISO 6474).

Compared to other currently used bearing couples, modern COC bearings demonstrate the lowest wear rates both in vitro and in vivo. For this reason, excellent clinical performance can be expected. The aim of this paper is to review the advantages and disadvantages associated with current COC THA.

LITERATURE SEARCH

PubMed (1996-2011) was meticulously searched to detect studies reporting clinical outcomes for COC THA using the following keywords and their combinations: “total hip arthroplasty/replacement”, “ceramic”, “ceramic on ceramic”, “aseptic loosening”, “osteolysis”, and “complications”. The relevant data including ceramic material,
number of patients/hips, period of implantation, primary
diagnosis, average age at the time of surgery, sex, mean
follow-up, survivorship, revision rate and reasons for revi-
sion were extracted. In addition, the best available data
for non-COC THA were searched for the same period
using identical search strategy except the word “ceramic”.
Finally, literature pertinent to material characteristics of
COC THA was searched using Google.

ADVANTAGES OF CERAMIC-ON-CERAMIC THA

Tribological remarks

Current ceramics used for manufacturing bearing sur-
faces in THA exhibit outstanding tribological properties,
the most important of which are hardness and high degree
of wetability. Ceramic has a greater hardness than metal
and can be polished to a much lower surface roughness
while excellent wetability ensures that the synovial fluid
is uniformly distributed between implant surfaces\(^3\). The
former guarantees high resistance to major scratches and
undetectable wear rate, while the latter facilitates fluid-film
lubrication thus contributing to very low friction between
articulating surfaces (< 1.7x10\(^{-7}\) mm\(^3\)/Nm) (ref.\(^4\)).

The basic mechanism of wear in COC articulations is
intergranular erosion followed by isolated grain pull-out\(^6\).
In fact, hip simulator studies of current COC bearings
have shown very low wear rates (less than 0.1 mm\(^3\) per
million cycles) (ref.\(^7\)). However, measurement of retrieved
ceramic implants revealed much higher wear rates than
above (≥ 1 mm\(^3\)/yr.) and a characteristic “ceramic” wear
pattern was noted\(^8\). The reason for these differences
could lie in different biomechanical conditions in vitro
and in vivo, with the latter being exposed to edge load-
ing, recurrent separation of bearing surfaces and even
direct impingement of the ceramic implant on the neck
of the stem, that increase the total wear of the implant in vivo.
However, even under microseparation conditions,
the wear rates of current alumina and ZTAMC ceramics
are lower than highly cross-linked polyethylene (up to 1.8
mm\(^3\)/million cycles) (ref.\(^7\)).

Size of ceramic particles

Ceramic wear particles are continually released into
the effective joint space during each step similar to non-
COC THA. Depending on the mechanism of wear, ce-
ramic particles are typically generated in smaller numbers
and with a bimodal size range involving nanometer size
particles (mean 24 nm; range 5 to 90 nm) and larger par-
ticles (mean 0.43 μm; range 0.05 to 3.2 μm) probably as-
associated with grain boundary fracture\(^6\). In addition, even
larger ceramic particles are generated during gross dam-
age (catastrophic failure) of the bearing surfaces (Fig. 1).

Table 1. Characteristics of ceramic materials used currently in total hip arthroplasty.

| Type of ceramic | Grain size (μm) | Density (g/m\(^3\)) | Bending strength (MPa) | Fracture toughness (MPa.m\(^{1/2}\)) | Vickers hardness | Young’s modulus (GPa) |
|-----------------|----------------|---------------------|-----------------------|----------------------------------|-----------------|---------------------|
| Alumina (BIOLOX FORTE) | < 2 | 3.98 | 580 | 4 | 20 | 380 |
| Zirconia | < 0.5 | n.a. | > 900 | 8 | 12.5 | 210 |
| ZTAMC (BIOLOX DELTA) | < 2 | 4.37 | > 1380 | 6.5 | 19 | > 350 |

ZTAMC – Zirconia-toughened alumina matrix composite; n.a.-not available. Sources: CeramTec AG, Plochingen, Germany

Fig. 1. Left hip revised due to catastrophic failure of ceramic liner (a); metallosis with gross fragments of broken ceramic liner (b).
Biological activity of ceramic particles

Prosthetic particles released from artificial joints stimulate periprosthetic cells to produce an inflammatory and pro-osteolytic environment leading eventually to alteration of local bone homeostasis in favour of bone resorption. Generally, the impact of particle load on the extension of bone defects depends at least on the size, amount, origin, and shape of the particles\textsuperscript{11}. COC THAs exhibit very low ceramic wear rates and in addition, ceramic wear particles have much lower specific and functional biological activity than polyethylene particles\textsuperscript{12-13}. Catelas et al. showed that polyethylene particles stimulated greater release of TNF-α when compared to alumina or zirconia\textsuperscript{14}. Kubo et al. found much less intense histiocytic response around particles of alumina ceramics (3.9 μm in diameter) than that of UHMWPE (11 μm), stainless steel (3.9 μm), and CoCr (3.9 μm) in a rabbit model\textsuperscript{15}. Bos et al. studied macrophages in the pseudo-synovial membrane from well-fixated implants retrieved at autopsy and found the percentage of macrophages was higher in the polyethylene-on-ceramic and metal-on-polyethylene groups (40-60%) than in the ceramic-on-ceramic group (20-40%) (ref.\textsuperscript{16-17}). On the other hand, at least one study comparing macrophage apoptosis as a result of stimulation by alumina, zirconia, and PE particles found the response to be size and concentration dependent, rather than particle composition dependent\textsuperscript{11}. The overall impression is that ceramic particles are biologically inert, but if released in sufficient numbers (e.g. cases of neck impingement or third body wear), ceramic particles can produce osteolysis similar to that induced by PE particles. In comparable doses, however, the biologic response is less intense with ceramic versus PE particles.

From the above, it could be deduced that osteolysis and aseptic loosening will be obviated in patients with COC THA. Unfortunately, this is controversial because

Table 2. List of the selective studies reporting survivorship for COC and non-COC THAs; unfortunately the majority of retrieved studies have several inconsistencies in reporting (e.g. unclear number of patients and hips, survivorship without the Kaplan-Maier statistical analysis, unreported 95% confidence interval) precluding direct comparison in above terms.

| Author          | Bearing pair | Number of patients | Number of THAs | Period of implantation | Average age (yrs.) | Range from to (yrs.) | Follow-up term | Survivorship (%) | 95% CI (confidence interval) |
|-----------------|--------------|--------------------|----------------|------------------------|-------------------|---------------------|----------------|------------------|--------------------------|
| Milosev et al.\textsuperscript{48} | M-M         | 591                | 640            | 1994-2002              | 57                | 18-80               | 10             | 91               | 88-95                    |
| Neumann et al.\textsuperscript{49} | M-M         | 99                 | 100            | 1995-1996              | 56.7              | 36-75               | 10             | 94               | 89-99                    |
| Migaud et al.\textsuperscript{50} | M-M         | 30                 | 39             | 1995-1998              | 39.8              | 23-49               | 12             | 100              | NA                      |
| Neuerburg et al.\textsuperscript{51} | M-M         | 1121               | 1270           | NA                    | NA                | NA                  | 10             | 90               | 86-94                    |
| Delaunay et al.\textsuperscript{52} | M-M         | 73                 | 83             | 1995-2004              | 40.7              | 23-49               | 10             | 100              | 89.6-100                 |
| Kim et al.\textsuperscript{53} | C-HPE       | 71                 | 73             | 2000-2002              | 45.5              | 20-50               | 8.5            | 100              | 98-100                   |
| Garavaglia et al.\textsuperscript{54} | C-HPE      | 518                | 561            | 1996-1998              | 69.3              | 24-98               | 10             | 98.8*             | 97.4-99.5*                |
| Grobler et al.\textsuperscript{55} | M-HPE       | 93                 | 100            | 1991-1993              | 54                | 24-71               | 10             | 100              | NA                      |
| Zweymüller et al.\textsuperscript{56} | C-P         | 365                | 376            | 1993-1994              | 62.8              | 20-83               | 10             | 99.3             | 96.9-99.8                |
| Epinette et al.\textsuperscript{57} | C-P         | 384                | 418            | 1989-1991              | 69.6              | 21-88               | 10             | 98.2             | NA#                     |
| Kim et al.\textsuperscript{53} | C-P         | 78                 | 109            | 1991-1993              | 46.8              | 21-49               | 10             | 93.6             | NA                      |
| Wroblewski et al.\textsuperscript{58} | C-P         | NA                 | 3611           | 1962-2005              | 67                | 12-93               | 10             | 97.5*            | 97.0-98.0*               |
| Chevillotte et al.\textsuperscript{59} | C-C         | 92                 | 100            | 1999-2000              | 52.3              | 20-73               | 9              | 95.8             | NA                      |
| Murphy et al.\textsuperscript{60} | C-C         | 173                | 194            | 1997-2003              | 49.9              | 18-76               | 9              | 96               | 91-100                   |
| Park et al.\textsuperscript{61} | C-C         | 90                 | 102            | 1999-2002              | 39                | 18-66               | 9.6            | 95.3             | 89.5-100                 |
| Mesko et al.\textsuperscript{62} | C-C         | 848                | 930            | 1996-2000              | 51.3              | NA                  | 10             | 96.8             | 94.6-98.1                |
| Boyer et al.\textsuperscript{27} | C-C         | 76                 | 83             | 1993-2003              | 39                | NA                  | 10             | 92               | NA##                    |
| Lee et al.\textsuperscript{28} | C-C         | 84                 | 100            | NA                    | 41                | 18-65               | 10             | 99               | 97-100                   |
| D’Antonio et al.\textsuperscript{29} | C-C         | 189                | 216            | NA                    | 53.1              | 30-73               | 10.3           | 97.9             | 91.9-99.5                |
| Kress et al.\textsuperscript{29} | C-C         | 71                 | 75             | 1997-1999              | 58                | 34-77               | 10.5           | 97               | NA                      |
| Sugano et al.\textsuperscript{63} | C-C         | 87                 | 100            | 1996-1998              | 56                | 41-73               | 14             | 95.7             | 89.0-98.4                |

NA – not available, M-M – metal-on-metal, C-HPE – ceramic-on-highly cross-linked polyethylene, M-HPE – metal-on-highly cross-linked polyethylene, C-P – ceramic-on-conventional polyethylene, C-C – ceramic-on-ceramic, # – survivorship, calculated using revision for all causes at 10 years, was 98.24%±0.0167, ## – the 10-year overall survival rate, considering failure to be revision for any cause, was 92±11%, * – survival analysis with revision for a loose acetabular component as the end-point.
### Table 3. Summary for a review on ceramic on ceramic THA.

| Parameter                              | Ceramic on Ceramic | Ceramic/Metal on Polyethylene | Metal on Metal |
|----------------------------------------|--------------------|-------------------------------|---------------|
| Wear rate                              | 30.5±7 μm/y⁶⁴      | 218.2±13.7 μm/y⁶⁴             | 20–25μm/y⁶⁵  |
| Particle size                          | 0.13–78 μm⁶⁶       | 30 nm–10 μm⁶⁷                 | 30–100 nm⁶⁸  |
| Cellular response to wear particles    | Low                | High                          | High          |
| Hypersensitivity induced by wear debris| No                 | No                            | Yes           |
| Tissue necrosis, ALVAL                 | No or weak         | Weak                          | High grade    |
| Dislocation#                           | 0.78%              | 0.80%                         | 0.74%         |
| Infection#                             | 0.32%              | 0.49%                         | 0.53%         |
| Mechanical loosening#                  | 0.39%              | 0.22%                         | 0.20%         |
| Revision#                              | 1.02%              | 1.16%                         | 1.12%         |
| Noisy hip                              | Up to 33%          | Rarely                        | Less frequent |
| Survivorship, 10 yrs. FU               | 99% (95% CI; 97–100%)²⁸ | 95.6% (95% CI; 90.1–98.3%)⁶⁹ | 95.4% (95% CI; 85.8–99.8%)⁷⁰ |
| Survivorship, 20 yrs. FU               | 84.4% (95% CI; 0.56–1.33)²³ | 81.8% (95% CI; 79.0–84.6%)* | 84% NA⁷¹     |

# – up to 2 years of follow-up; ALVAL – aseptic lymphocytic vasculitis-associated lesions; FU – follow-up; * – 22 y. survivorship of Lubinus SP II for all diagnoses and all reasons for revisions (Swedish Hip Arthroplasty Report 2008); NA – not available

### Table 4. The incidence of squeaking (from the lowest to the highest incidence).

| Published | Author          | State        | Ceramic material | Period of implantation | Number of patients | Number of THAs | Average age (yrs.) | Follow-up (yrs.) | Incidence of squeaking | Incidence of all noises |
|-----------|-----------------|--------------|------------------|------------------------|--------------------|----------------|-------------------|-------------------|------------------------|------------------------|
| 2010      | Park et al.⁶¹   | South Korea  | NA               | 1999-2002              | 90                 | 102            | 39                | 9.6               | 0%                     | NA                     |
| 2011      | Sugano et al.⁶³ | Japan        | Biolox forte     | 1996-1998              | 87                 | 100            | 56                | 14                | 0%                     | 0.01%                  |
| 2007      | Lusty et al.⁷³  | Australia    | Biolox forte     | 1997-1999              | 283                | 301            | 58                | 7.6               | 0.3%                   | NA                     |
| 2008      | Capello et al.⁷⁴| USA          | Biolox forte     | 1996-1998              | 452                | 475            | NA                | 8.3               | 0.8%                   | NA                     |
| 2011      | Mesko et al.⁶²  | USA          | NA               | 1996-2000              | 848                | 930            | 51.3              | 10                | 0.97%                  | 2.5%                   |
| 2011      | D’Antonio et al.⁷⁶| USA         | NA               | 1996                   | NA                 | 144            | 53.1              | 10.3              | 1.4%                   | NA                     |
| 2011      | Schroder et al.⁷⁵| USA         | NA               | 2003-2006              | 317                | 375            | 54                | 3.0               | 1.9%                   | 11.0%                  |
| 2011      | Cogan et al.⁷⁶  | France       | NA               | 2003-2004              | 238                | 284            | 52.4              | NA                | 2.6%                   | 10.6%                  |
| 2010      | Restrepo et al.⁴⁹| USA         | NA               | 1998-2004              | 266                | 304            | 45.5              | NA                | 2.7%                   | NA                     |
| 2011      | Sexton et al.⁷⁷ | Australia    | NA               | 1997-2008              | NA                 | 2 406          | NA                | 9.4               | 3.1%                   | NA                     |
| 2009      | Greene et al.⁷⁷ | USA          | NA               | 2003-2005              | 97                 | 103            | 52.6              | 4.2               | 4.9%                   | NA                     |
| 2011      | Chevillotte et al.⁷⁹| France | Biolox forte | 1999-2000              | 92                 | 100            | 59                | 9                 | 5.4%                   | NA                     |
| 2009      | Jarrett et al.⁷⁴| USA          | NA               | 2003-2005              | 143                | 159            | 52                | 1.8               | 10.7%                  | 32.8%                  |

NA – not available
several studies demonstrated periprosthetic osteolysis even in patients with current COC THA (ref.19,20). The reason may lie in the multifactorial origin of osteolysis and aseptic loosening when particle related parameters play an important role but not the only pathway inducing these entities21. In addition, ceramic bearing surfaces are not the only source of prosthetic particles. In support of this is a histological study of pseudomembranes from loosened alumina cups that suggested that this “unexpected” osteolysis was probably due to metal or cement debris rather than alumina particles1. Thus, in terms of biological activity of ceramic particles, the advantages clearly outweigh the disadvantages.

Clinical evidence for ceramic-on-ceramic THA

Assuming that COC bearings offer the lowest wear rates and that ceramic particles induce minimal adverse biological activity, do these facts result in overall improvement in survivorship of THA?

Recent systematic reviews on survivorship of hard-on-hard bearings in THA revealed variable implant longevity and rates of complications in earlier studies (survival rates of 73% to 100% at mean follow up ranging from 31 to 240 months) (ref.22). Early generations of ceramic-on-ceramic implants were characterized by high failure rates as a result of both component fracture and loosening of the monolithic acetabular component. However, in a recent retrospective study, Petsatodis et al. reported a survivorship of 84.4% of cementless alumina COC prostheses at 20 years follow-up23. Others have reported significant differences in survivorship of COC bearings depending on the type of prosthesis and its fixation, especially with respect to cementless and cemented cups24-25. Therefore, the survivorship and rate of complications of ceramic bearing surfaces depend not only on the period of implantation (and therefore the generation of ceramic material), but also on other important factors e.g. design of the prosthesis, surgical technique and the method of femoral and acetabular fixation2.

The new generations of ceramic implants suggest more promising outcomes (Table 2), especially in young and active patients, with survivorship rates (free of revision) between 92% and 99% at ten years of follow-up26-30. However, these data are comparable but not better than the best outcomes for both metal-on-metal and metal/ceramic-on-polyethylene articulations (Table 2). In addition, the number of studies and length of follow-up for COC bearings are still insufficient compared to ceramic/metal-on-polyethylene THAs. Finally, the strength of evidence might be further compromised by methodological weaknesses as was reported for other clinical research in orthopaedics31.

As a result the conclusion is that use of highly wear resistant bearing surfaces does not automatically guarantee longer survivorship than the best non-COC THAs. The reason lies at least partially in the occurrence of other unrelated complications (e.g. deep sepsis, instability, peri-prosthetic fracture etc.) that require revision surgery and that are not prevented by simple choice of bearing surface (Table 3). Even aseptic loosening cannot be completely resolved using one specific bearing surface because of its multifactorial etiology32. On the other hand, the rate of osteolysis was diminished as a direct consequence of using ceramic bearings. Taken together, combining the best design of THA with COC bearings might improve the long-term outcomes. However, this remains to be demonstrated in well-conducted multicentre studies and/or arthroplasty registries data.

DISADVANTAGES OF COC BEARINGS IN THA

Ceramic head and liner fractures

Ceramic head and liner fractures are associated with massive metallosis and exposure of the local tissues to particles of titanium or cobalt-chromium alloy from the metallic components (Fig. 2). Earlier generations of alumina ceramic heads had a reported risk for fracture between 0.26% and 13.4%, however for newer implants (Biolox Forte) the reported fracture rate is much lower at 0.004 to 0.015% (ref.33). Representative data for Biolox Delta are not currently available.

The risk of ceramic liner fracture in new generation ceramic materials has been reported to be between 0% and 5.3%, with a higher incidence among sandwich-type
ceramic cups than 1-piece components. Szymanski et al. who reported 5.3% (7/132) of ceramic liner fractures (sandwich type implant) at a mean 32 months after the surgery also revealed clinical risk factors for fracture45. These included excessive weight, advanced age, dislocation, prosthetic impingement, and increased postoperative hip offset. In an FDA multicenter study, new composite ceramic materials (Biolox Delta alumina-on-alumina ceramic; one-piece component) exhibited no ceramic fracture within 3 years of follow-up35. However, these materials have a relatively short clinical history, so further monitoring is necessary.

Squeaking

Another concern remains squeaking of ceramic bearings. This potentially affects the patient’s quality of life and survivorship of the implant due to revision of the squeaky hip. Noises emanating from ceramic bearings (usually clicking and squeaking) have been reported with rates that vary from 0% to 33% (Table 4).

Currently there are several theories on the origin of squeaking but the exact mechanism is still unclear, and is likely multifactorial. Some authors reported that squeaky hips are associated with younger active, heavier, and taller patients36-37. Parvizi et al. revealed an association with a particular prosthetic design that enabled neck impingement on the metallic rim of the cup38,39. Similarly, Restrepo et al. found a clear relationship between the prevalence of squeaking and the type of femoral component implanted40. Alternatively, there are studies that did not report any squeaky hips even after 10 years of follow-up (Table 4). Other explanations for COC squeaking include localized “striped” wear, changes of fluid film lubrication conditions and femoral head microseparation41-42. As a ceramic head passes over the wear stripe, it could generate a vibration and the metallic parts (femoral head and acetabular shell) amplify this vibration by resonating, resulting in an audible sound. This explanation is consistent with the fact that COC squeaking does not occur until an average of fourteen to eighteen months after surgery. Finally, squeaking could be generated by the rolling/sliding motion of the femoral head inside the liner in the current generation of COC THAs (ref.43). Manufacturers have introduced acetabular shells with different liner materials that are interchangeable, possibly leading to a diameter mismatch in some cases that allows a rolling/sliding mechanism. Regardless of which theory is plausible, noisy hips can occur in up to 33% of hips with COC bearings; fortunately clinically the problem is often minor in the majority of patients with current COC THA will experience asymptomatic ongoing generation of wear debris and low risk of head or liner fracture. Toni et al. recommended performing an X-ray/CT examination in patients with noisy COC THA to distinguish between snapping hips and hips with macro-damaged bearing surfaces44. If the examination is negative then the authors recommend joint fluid aspiration to detect ceramic particles due to minor surface damage.

Concerns related to revision of ceramic-on-ceramic THA

One important clinical question is how to identify impending catastrophic failure of COC THA because it can occur suddenly without prior symptoms. In addition, the majority of patients with current COC THA will experience asymptomatic ongoing generation of wear debris and low risk of head or liner fracture. Toni et al. recommended performing an X-ray/CT examination in patients with noisy COC THA to distinguish between snapping hips and hips with macro-damaged bearing surfaces44. If the examination is negative then the authors recommend joint fluid aspiration to detect ceramic particles due to minor surface damage.

Another problem is the stable cup with a one-piece ceramic liner because it may be difficult to remove the ceramic liner from the metallic cup. The removal of a ceramic liner from the shell can be accomplished by a strong perpendicular impact to the rim of the shell, which might disrupt the press fit forces of the conical liner (personal communication with Karl Knahr). The inner surface of the shell must not be damaged during this impact to avoid the necessity of removal of the damaged shell. A special suction cup instrument has been developed to facilitate removal of ceramic liner out of the metal shell without damaging the metal. However, it is ineffective in firmly fixed liner.

Another important question relates to whether a new ceramic head should be implanted on a non-revised stem neck (trunion) after removal of the previous ceramic head. Potential damaged areas of the taper by forceful removal of the previous head may later serve as stress risers (Fig. 3) that can initiate and propagate a crack that ultimately leads to a fracture of the newly implanted head. When a metallic ball is implanted to replace a fractured ceramic head, care must be taken to remove all ceramic particles from the joint cavity because alumina particles remaining in the surrounding tissues could cause third body wear of the new metallic ball. In this situation, the ceramic par-

Damage of the ceramic rim

Direct contact between the neck of the stem and the rim of the ceramic liner during range of motion can result in rim damage. Ceramic fragments can then impose themselves between the ceramic surfaces contributing to accelerated wear. Under some circumstances forceful impingement can even result in dislocation of THA. Stafford et al. revised 6 hips with COC THAs; three of which were

![Fig. 3. Trunk of the stem can be damaged after forceful removal of the original head which could deform neck surface of the stem; these deformations could induce places of increased strains and stresses in conjunction with a new ceramic head; original situation after index surgery (a); placement of a new ceramic head on damaged neck of the stem (b)](image)
articles, which are harder than metal, might damage a metal head in a short time. This is why some specialists advise against the use of a metal head in the scenario of revision due to a fractured ceramic head/liner. Accordingly, only revision to COC or ceramic-on-polyethylene is recommended in this case. A special revision head system that consists of toughened dispersion ceramic ball along with titanium sleeve has been developed which allows the surgeon to retain the stem and use the original trunion (e.g., BIOLOX® OPTION; CeramTec, Germany). If the above-mentioned sleeve is not used, it is strongly recommended to exclude the possibility that the retained stem taper is damaged by close gross visual inspection.

CONCLUSION

The newest alumina/composite ceramic bearing surfaces have only negligible risk for fracture of the head and liner, and exhibit very low wear rates. The most recent ten-year follow-up studies have demonstrated comparable survivorship with current ceramic/metal-on-polyethylene and even metal-on-metal bearing couples. The most important current concerns about COC bearings are squeaking, and component impingement and micro-separation, increasing the risk of surface damage and premature prosthetic failure. Risk for fracture of ceramic sandwich-type liners also remains a subject of concern. From the foregoing, the advantages and disadvantages of current COC THA should be carefully considered in younger, more active patients.

ACKNOWLEDGEMENT

This study was supported by Internal Grant Agency of the Ministry of Health, Czech Republic (NT/11049-5).

CONFLICT OF INTEREST STATEMENT

Author’s conflict of interest disclosure: The authors stated that there are no conflicts of interest regarding the publication of this article.

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