Surgeon’s insights

Ceramic on Ceramic in Revision Total Hip Arthroplasty

Literature and Experience at IOR

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Introduction

Ceramic components and ceramic on ceramic (CoC) bearings have a proven track record for more than 40 years in several millions of total hip arthroplasty (THA) implants. Especially the latest generation of ceramics (AMC; BIOLOX® delta) has, for more than 10 years in clinical use, demonstrated its proposed advantages for primary THA over other bearing options. This has been confirmed by several studies and recently additional evidence and benefits have been shown with respect due to:

- Biocompatibility – bulk and particles; no known ALTR (Esposito 2013)
- Use of larger heads with smaller cups without disadvantages like increased friction and wear (Pandorf 2007, 2013, Streicher 2013)
- Material stability – no ion release (Beraudi 2014, Kretzer 2014)
- Reduced corrosion of the modular stem taper; no corrosion itself (Kurtz 2013)
- Negligible wear and wear particles (Häussler 2013, Clarke 2009, Esposito 2013)
- Lower friction and friction torque (Bishop 2013, Morlock 2014)
- Increased resistance to biofilm formation in-vitro (Piconi 2015)
- Reduced infection risk (Streicher 2014/2015)
- Particle algorithm according to Krenn (Z. Rheumatolog. 2014)
Therefore the numbers of total hip arthroplasties have increased steadily, including more and younger and active patients. Nevertheless, it is expected that the greater number of primary arthroplasties will lead to a greater number of revisions, also including younger and more active patients. It is expected that the advantages of CoC will be as prominent in revision THAs (R-THA) as in primary THAs. We discuss the results of ceramic on ceramic bearing surfaces in case of revisions and after failed implants with various bearing surfaces on the bases of the available literature and our own experience at the IOR.

CoC for Revision THA

Reviewing the literature shows that the information and publications on CoC for R-THA are scarce and only few references could be identified. Aside from case reports and review articles, relatively few studies have previously been published exploring outcomes of ceramic bearings in revision THA (Wong 2015, Khatod 2015, Koo 2014, Yoo 2013, Jack 2013, Hannouche 2010, Chang 2009, Allain 2003, Kurtz 2015, Sharma 2010, Hintner et al. 2011, Thorey et al. 2011, Traina et al. 2011). Previous studies focused on revision outcomes during special circumstances, such as revision after ceramic fracture (Koo 2014, Allain 2003, Sharma 2010); revision in patients with osteolysis (Yoo 2013); or revision after failed metal-on-metal hip arthroplasty (Wong 2015). As the demand for revision surgery is expected to increase, there has been interest in studying revision surgery outcomes for ceramic bearings in the general patient population (Khatod 2015, Jack 2013, Chang 2009, Kurtz 2015).

With the growth of revisions around the world and concern about the durability of revision surgery, there is a growing body of literature that focuses on the use of ceramic bearings for routine, all-cause revision surgery. These studies, which are summarized in Table 1, support that revision with CoC bearings is not only safe and effective, but also highly successful, which some clinical series reporting over 95 % survivorship without re-revision after 5-7 years follow-up. It is also clear from these studies that the risk of ceramic fracture following revision surgery is extremely low, even considering that most of the studies have documented outcomes for alumina CoC bearings. Thus, the risk of fracture following revision surgery with CoC appears to be acceptably low, comparable to primary surgery.

In general, the revision outcome studies are limited to single center series, with the exception of the research by Khatod et al. 2015, who followed the outcomes of revision surgery in the Kaiser Permanente integrated health system between 2001 and 2010. During this time period, there were 629 revision surgeries for a variety of reasons, of which 63 were re-revised (10 %). Ceramic-on-highly crosslinked polyethylene (C-HXLPE) was used in the treatment of 13.7 % (86/629) of the index revisions; metal-on-crosslinked polyethylene (M-HXLPE) was the largest treatment group (42.3 %, 266/629). In examining the reasons for re-revision using multivariate Cox regression, they observed significant patient, surgeon, and implant factors. Among the implant factors, the use of ceramic head against HXLPE was found to significantly reduce the risk of re-revision (odds ratio: 0.32; 95 % CI: 0.11 to 0.95; p = 0.04).

### Table 1: Summary of clinical outcomes reported for ceramic bearings in R-THA.

<table>
<thead>
<tr>
<th>Study</th>
<th>Number of hips</th>
<th>Index Revisions due to Aseptic Loosening (%)</th>
<th>Mean follow-up in years (range)</th>
<th>Bearing Used for Revision</th>
<th>Fractures (%)</th>
<th>Kaplan Meier Survival (Re-Revision)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hannouche et al.</td>
<td>110</td>
<td>83 %</td>
<td>9.3 (5 to 27)</td>
<td>COC, 28 % (31/110); C-PE, 58 % (64/110); M-PE, 14 % (15/110);</td>
<td>-</td>
<td>83.1 % “revision for mechanical failure” at 10 years</td>
</tr>
<tr>
<td>Chang et al.</td>
<td>42</td>
<td>64 % (27/42)</td>
<td>5.4 (3.2 to 8)</td>
<td>COC, 100 % (alumina)</td>
<td>-</td>
<td>100 % (no re-revisions)</td>
</tr>
<tr>
<td>Yoo et al.</td>
<td>64</td>
<td>59 % (38/64)</td>
<td>9.8 (7.0 to 13.1)</td>
<td>COC, 100 % (alumina)</td>
<td>-</td>
<td>96.9 % at 7 years</td>
</tr>
<tr>
<td>Jack et al.</td>
<td>165</td>
<td>98 %</td>
<td>4.8 (2.1 to 12.5)</td>
<td>COC, 100 % (100 alumina, 65 delta) 2 alumina heads</td>
<td>96.6 % femur, 94 % acetabulum at 8.3 years</td>
<td></td>
</tr>
<tr>
<td>Khatod et al.</td>
<td>629</td>
<td>14.3 %</td>
<td>5</td>
<td>C-PE (13.7 %)</td>
<td>-</td>
<td>86.8 % at 5 years</td>
</tr>
</tbody>
</table>
CoC in revisions due to osteolysis

In cases of THA revisions for aseptic loosening/osteolysis CoC bearings are a valuable option due to their excellent biocompatibility and wear resistance. Various authors have reported that CoC bearings can be used very successfully to help in reducing or even halting the progression of osteolytic lesions.

Jack et al. 2013 reported on 165 revision surgeries, mostly due to aseptic loosening, which were revised with CoC bearings. After revision there was no progression of lesions. Yoo et al. 2013 report on the results of 64 THA revisions due to osteolysis. All were revised with a CoC bearing. No progression of osteolysis was found at 7 years follow up.

Kim et al. 2011 and Park et al. 2011 reported on the revisions of a few THAs in patients with metal-on-metal (MoM) bearings with osteolytic lesions. The lesions seemed to reduce (radiographic evidence) after revision to CoC bearings.

CoC in revisions due to ALTR

In recent years, there has been growing interest in the management of patients who are revised after adverse local tissue reactions to metal particles, either due to MoM hip bearings, or taper corrosion in M-PE bearings (Wong 2015, Cooper 2012, Plummer 2015). If a patient is revised secondary to an adverse reaction to metal, such as taper corrosion, there is a growing consensus in the clinical community that ceramic components should be used for the revision (Cooper 2012, Plummer 2015, Carli 2015). Initially the clinical evidence in support of this recommendation was indirect. For example, we know that taper corrosion and metal release will be mitigated by the use of ceramic head (Kurtz 2013). However, there are only a few outcome studies that address revision outcomes after ALTR using ceramic bearings (Wong 2015, Cooper 2012, Plummer 2015).

Researchers working in collaboration with the Australian registry examined the outcomes of revision of 844 MoM hip resurfacing procedures between 1999 and 2012 (Wong 2015). The most frequently reported reasons for the index revision were loosening, osteolysis, metal related pathology and fracture. There were 102 cases of re-revision in this cohort, and the overall risk of re-revision was 26 % at 10 years. They found no difference in the risk of re-revision based on the bearing surface used in the index revision surgery. The most commonly used bearing surface in these revisions, ceramic on ceramic, had a re-revision rate of 14 %. The odds ratio for CoC re-revision was 0.46 (95 % CI: 0.16-1.29), p = 0.141, which suggests a trend, but as reported was not statistically significant. Indeed, their study was underpowered to detect differences relative to a re-revision rate of 67 % in cases where a MoM bearing was used in the revision surgery. The authors stated that an
even larger number of patients than they studied would be needed to detect a difference in outcomes by bearing surfaces.

Researchers from Rush University in Chicago have described the treatment of a small series of patients who were revised with a metal-on-polyethylene (MoP) bearing due to adverse reactions associated with taper corrosion (Cooper 2012, Plummer 2015). Their original case series included 10 patients (Cooper 2012), but recently, the outcomes for 27 revision patients with short-term follow-up have been published (Plummer 2015). In 23/37 patients treated with a ceramic head and a Ti taper adapter sleeve, there were no recurrences of adverse local tissue reactions, whereas in the 4 patients treated with CoCr heads, there was one reoccurrence. Among 18 patients with two years follow-up, there was a significant decrease in blood serum Co and Cr levels as compared with previous revision. The authors advocated retention of a well-fixed stem and the use of a ceramic femoral head with a taper adapter sleeve as a reasonable option for the revision of MoP hips secondary to adverse local tissue reactions and taper corrosion. Pseudotumor-like periprosthetic tissue reactions around metal-on-metal hip replacements can cause pain and lead to revision surgery. The cause of these reactions is not well understood but could be due to excessive wear, or metal hypersensitivity. The tissue features may help distinguish reactions to high wear from those with suspected metal hypersensitivity.

The pattern and type of inflammation seen in tissue obtained from the sites of total hip prostheses with MoM bearings are very different from those of tissues obtained from the sites of total hip prostheses with metal-on-polyethylene bearing surfaces. A prominent feature associated with failed metal-on-metal bearing surfaces is perivascular lymphocytic infiltration, the clinical implication of which is still not clear. An immunological response has been suggested, as has the possibility of early osteolysis secondary to a delayed type of metal hypersensitivity. This is in contrast to no known reaction with CoC bearing surfaces (Khatod 2015, Yoo 2013, Koo 2014, Jack 2013).

Several case reports or reports of case series showed a reduction or complete resolution of (ALTR) symptoms in patients with MoM or MoP bearings after revision to CoC bearings.

Kemp et al. 2013 identified 3 patients with pseudotumour formation after MoM resurfacing. All patients were revised with a CoC bearing. The authors state that: “progressive and satisfactory resolution of the associated pseudotumours was identified following revision of the prostheses to CoC THA”.

Maurer-Ertel et al. 2011 present a case report of a patient with MoM resurfacing who developed a solid cystic lesion in the iliopsoas muscle. The mass was resected but the bearing was not exchanged. After a few months the patient complained of pain, feeling of instability and recurrent swelling. Lab results also showed elevated metal ion levels. The patient was then revised to a CoC bearing, with no signs or recurrence after 10 months. Metal ion levels had also decreased significantly. According to Mao et al’s 2012 case report a patient with THA with an MoP bearing with suspected adverse reactions to metal debris, a cyst and elevated metal ion levels was revised to a CoC bearing. After 9 months the patient is systemically well and pain free with no recurrence of the cyst.

Rajpura et al. 2011 present 13 revision cases for ALVAL after MoM resurfacing or MoM THA (ALVAL diagnosis was confirmed histologically). All patients presented with unexplained groin pain. Bursal
swelling was the most consistent finding intra-operatively. In the revision procedures 2 THA with MoP bearings and 10 with CoC bearings were used; one patient was left with a pseudoarthrosis. After revision all patients reported immediate improvement in pain. However, 2 further revisions due to femoral neck fracture with pain were revised to a MoP bearing, but pain symptoms persisted until the bearings were exchanged to an alternative bearing.

Another example of a patient with a pseudotumour due to a THA with a MoXPe bearing is described by Walsh et al. 2012. The patient presented with pain and a growing mass. The patient was diagnosed with an inflammatory pseudotumour and was revised to a CoC bearing; at 1 year follow up the patient was asymptomatic.

In a case report by Whittingham-Jones et al. 2012 a patient had been revised to a MoP bearing after ceramic fracture with the result of extensive metallosis and highly elevated metal ion levels. The patient was revised to a CoC bearing (BIOLOX® delta) and is doing well after 18 months with significantly decreased ion levels.


**CoC in revisions reduce the risk of dislocation**

A retrospective analysis by Jo et al. 2015 was conducted on 539 hips undergoing revision total hip arthroplasty done for instability to report the cumulative risk and factors associated with re-dislocation and re-revision. The cumulative risk of re-dislocation and re-revision for all causes was 34.5 % and 45.9 % at 15 years, respectively. Multiple variable analyses revealed history of 2 or more previous surgeries, use of head size less than 36 mm, and cup retention to be risk factors for re-dislocation and re-revision. The use of a constrained liner was protective against re-dislocation but was not associated with a lower re-revision rate. Understanding the risk factors associated with re-dislocation or re-revision may help with perioperative decision making in order to decrease the high failure rate seen in this study.

CoC revision THA has been associated with substantial (1 % vs 18 %) fewer dislocations than polyethylene bearing implants. The reasons of the lower rate of dislocation with ceramic-on-ceramic bearings was speculated to be related to observed differences in the periartricular muscles (fat atrophy or not) and quality of the capsular tissue with the two bearing surfaces. (Hernigou et al. 2013, and 2015). In a large cohort studies of elderly patients (Medicare Database), and also analysed for R-THA patients treated with CoC, there was reduced risk of dislocation (Hazard Ratio: 0.76, 95 % CI: 0.58-0.99, p=0.04) (Kurtz 2015).

**CoC is the best option for revision of a fractured ceramic component**

The in vivo fracture of a ceramic component is a serious complication requiring immediate revision. The revision of a fractured femoral head may be complicated. A ceramic femoral head typically fractures into multiple fragments, which may be difficult for the revising surgeon to completely clean from the surrounding tissues. If not removed, residual ceramic particles can lead to third body wear of a subsequently implanted polyethylene liner or metal femoral head (Allain 2003) with catastrophic results. Therefore, the use of a MoP or MoM bearing is contraindicated for revision of a failed ceramic bearing. The morselised ceramic particles can also damage the trunnion of a well-fixed stem, necessitating its replacement along with the head and liner (Koo 2014). For these reasons, early attempts at ceramic fracture revision had variable and, in some cases, unsatisfactory outcomes (Allain 2003, Koo 2014).

The earliest and largest series dealing with this issue was published by Allain and coworkers 2003, who studied revisions performed after fracture from a ceramic femoral head by pooling data from 105 cases that occurred in 35 different surgical centers between 1977 and 1999. Published in 2003, their study included 18 cup designs from 14 manufacturers. The initial femoral heads were fabricated from alumina or zirconia, but the new heads were fabricated from stainless steel (the largest group), alumina, nitrated titanium alloy, reinforced stainless steel, cobalt-chromium, and zirconia. Overall, this is a very inhomogeneous group of cases spanning two decades of clinical history in France. The inhomogeneities in this group strongly limit the ability to apply these historical findings to contemporary implants in clinical use today. Not with standing these limitations, Allain and coworkers (Allain 2003) concluded that: “The operative technique for the treatment of a ceramic head fracture was very variable in our series. Three parameters appeared to be important: cup revision, the material of the femoral head, and total synovectomy ....” Therefore, the Allain’s work supported the concept of third-body wear as a risk following ceramic head fracture, but the ability to make predictions about future implant survival appeared to depend upon both surgical treat-
ment factors (e.g., complete synovectomy) and implant variables (e.g., the choice of femoral head material). Stainless steel femoral heads had the worst outcome after revision, as they could be eroded by third body wear. Allain and colleagues advocated the use of a CoCr or ceramic femoral head in revision surgery to address the risk of re-revision due to 3rd-body wear and recommended that the stem be saved unless the taper was severely damaged.

In 2010, Sharma et al. described the long-term outcomes of revision surgery following ceramic head fractures. The primary surgeries in this small series of 8 cases were performed between 1990 and 1992 and 2nd-generation alumina, BIOLOX®, was used as the femoral head material in the primaries. Following fracture, the patients were treated emergently with a complete synovectomy. The patients all received a CoCr femoral head and a conventional polyethylene acetabular component at revision. The patients were followed after revision for 10 years, on average (range: 84-180 months). Two patients were lost to follow up, one patient was revised at 12 months due to infection, and another patient was revised at 8.5 years due to periprosthetic fracture. Long-term wear rate was 0.11 mm/y and was comparable to a matched group of 6 patients with a primary THA (0.14 mm/y, on average). The authors described their technique of achieving a complete anterior and posterior synovectomy, which they credited for the longevity of the revision surgeries with no evidence of 3rd-body wear.

In 2014, Koo and colleagues reported the outcomes of patients who were revised after fracture of 3rd generation alumina heads (BIOLOX® forte). The authors contended that these modern ceramics were “much sharper and harder than early generation ceramics, “and that the early revision treatment paradigms may not be applicable to revising fractures with contemporary ceramic implants. They studied 24 patients who were revised for ceramic fracture between 2002 and 2009. In all cases, the Morse taper of the stem was visibly damaged with multiple scratches but was not removed in 20 cases, due to concerns about damage to the proximal femur. The 20 stem retained revisions were replaced with CoC bearings in 16 cases and MoP in 4. Among the 4 cases in which the stems were replaced, 3 received CoC bearings and 1 received MoP. There were no revisions among the 4 cases in which the stem was replaced. However there were five revisions in the stem-retained group: two subsequent ceramic head fractures, two cases of metallosis among the patients with CoCr heads, and femoral osteolysis and stem loosening in a fifth patient. The authors warned that neither ceramic nor CoCr femoral heads should not be implanted on a scratched stem taper due to the risk of subsequent revisions for fracture (in the case of a ceramic head) or adverse local tissue reaction (in the case of a CoCr head).

Metal sleeves (mandatory) in revisions:

It is generally against manufacturer’s recommendations to use a ceramic head on an existing taper during revision surgery of a well-fixed femoral component because damage of the taper may increase the risk of ceramic fracture. Additionally, a component mis-match may lead to accelerated wear and early revision. The use of a metallic sleeve allows the surgeon to keep the well-fixed femoral stem and to use ceramic on ceramic bearing surfaces in case of revising the acetabular component alone, reducing the time of surgery and decreasing the perioperative complications.

Thorey et al. 2011 report on the currently largest study with BIOLOX®OPTION in 91 patients, of which 58 received a CoC bearing (the others received CoP). In the short term (2 years) all patients in this series showed marked improvement in pain and function and there were no further fractures or signs of fretting or corrosion in the short term. Lazennec et al. 2010 also showed good results in
The use of CoC for hip prostheses offers the potential to improve long term wear performance and produce a lower risk of postoperative instability, which address two of the most common forms of failure confronting patients undergoing revision THR in comparable to different bearing surfaces. Ceramic has been used as an articulating bearing material because of its exceptional material properties. It has superior wear resistance because it is extremely hard, with a high scratch resistance. It also has excellent biocompatibility and is chemically and hydrothermally stable.

Improving the quality and survivorship of hip prostheses is a concern for every hip replacement surgery. After failure of a primary hip prostheses the challenge for revision surgery rises to achieve durability and less local tissue reaction to the new prostheses. The use of CoC decreases the dislocation risk due to the opportunity of implementing large femoral heads and less fat atrophy and capsular degeneration.

After the increase observation of osteolysis in patients with primary THR, the use of CoC may halt or reverse the adverse reaction and increase the osteointegration to the prostheses. The use of a large femoral head and the low wear facilitate the use of CoC and solve the problems with osteolysis and recurrent dislocation.

In IOR we started to use ceramics since the 70's. In my practice in IOR we use CoC since 90's and we dealt with the first to the last generations of CoC. Upon the evolution of the latest generation of CoC, we increase the use in different cases of revision because it allows us to have various possibilities to solve even complex surgeries. With increasing age of our patients we encountered many elderly patients with failed primary THR due to osteolysis and bone resorption offering them CoC in case of revision; potentially decreasing the need for further revision surgery in the future. Moreover the use of CoC in young active patients is the best option to reduce the risk of another revision in the future.

We also encountered a lot of revision cases for hip prostheses after MOM and our choice for revising them is with CoC to eliminate the pain and soft tissue reaction to MoM.

The introduction of metallic sleeves allows the surgeon to retain a well-fixed femoral stem and to use ceramic on ceramic bearing surfaces in case of revising the acetabular component alone, reducing the surgery time, and decreasing potential perioperative complications.

Kim Y. et al. 2014 retrospectively reviewed 53 R-THA with the use of ceramic heads with metal sleeves with no case of ceramic fracture or osteolysis.

Recent studies of revision surgery, including the use of taper adapter sleeves, have focused on the use of ceramic heads in routine all cause revision surgery (Jack 2013). For example, Jack and colleagues have published the outcomes of revision surgery using ceramic heads with taper adapter sleeves, but these revisions replaced polyethylene bearings due to osteolysis and loosening. In all cases, the femoral component was well-fixed, and the bearing was exchanged to CoC. There were 100 alumina and 65 alumina matrix composite implants. With a mean follow-up of 4.8 years, the survivorship with any cause of failure was 96.6 % for the acetabular component and 94.0 % for the femoral component. The authors recommended the taper adapter sleeves as a useful tool for revision surgery.

It can be concluded that ceramic heads with metal sleeves are a safe and reliable option for revision hip surgeries.

Figure 5: Preoperative and 4 years F.U. radiograph of a revision total hip replacement of a 45 year old active female patient with ceramic-on-ceramic with retained femoral stem and a metal sleeve.

Conclusion

The use of CoC for hip prostheses offers the potential to improve long term wear performance and produce a lower risk of postoperative instability, which address two of the most common forms of failure confronting patients undergoing revision THR in comparable to different bearing surfaces. Ceramic has been used as an articulating bearing material because of its exceptional material properties. It has superior wear resistance because it is extremely hard, with a high scratch resistance. It also has excellent biocompatibility and is chemically and hydrothermally stable.

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The introduction of metallic sleeves allows the surgeon to retain a well-fixed femoral stem and to use ceramic on ceramic bearing surfaces in case of revising the acetabular component alone, reducing the surgery time, and decreasing potential perioperative complications.
In my experience I choose to use CoC in cases of revision is always superior and easy to deal with in comparison to other bearing surfaces, because it is safer and the best solution. This warrants a long life of the revision implant.