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Atraumatic Breakage of a 4th Generation BIOLOX Delta Ceramic Head in Total Hip Replacement: A Case Report

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Abstract

Despite the major improvements in ceramic bearing design, fractures can still occur. The development of the 4th-generation BIOLOX delta ceramic heads has reduced fracture rates to 0.001%; however, the risk, though extremely low, has not been entirely eradicated.

We present a case report of a 53-year-old man who suffered an atraumatic breakage of a BIOLOX delta ceramic femoral head three years postoperatively. Anamnestic and physical examination revealed a sensation of walking on gravel and a painful hip mobilization. Revision surgery involved a synovectomy and removal of ceramic fragments, followed by a replacement of the ceramic femoral head and poly-ethylene acetabular liner. The patient recovered well, with an uneventful follow-up.

This case adds to the scarce literature concerning atraumatic breakage of the latest generation BIOLOX ceramic head. To the best of our knowledge, only three prior cases have reported such fractures in a primary total hip replacement (THR) using ceramic-on-polyethylene (CoP) bearings.

Keywords: Ceramic head failure in THR

Introduction

THR is also referred to as "the operation of the century". The first ever hip replacement was performed by Wiles in 1938 and was later revolutionized in the 1950s by Charnley, in part by introducing high-density polyethylene as bearing material and using polymethyl methacrylate bone cement [1]. In the early 1970s, emerging issues, among them implant failure, drove innovation toward more advanced materials and fixation techniques [2].

Alumina ceramic heads in THR have been first introduced in the 1970s [3]. Their high wear resistance makes them an excellent alternative material for the earlier-developed metal bearings [2]. However, their inherent brittleness increases the risk of fracture, which prompted the development of next-generation ceramic bearings, including high-purity alumina ceramics (BIOLOX forte) and zirconia-toughened alumina ceramics (BIOLOX delta) [1,3]. With a fracture rate of 0,001%, fourth-generation BIOLOX delta ceramic femoral head fractures have become an exceedingly rare yet severe complication in primary THR, often requiring complex revision surgery [6,14]. BMI and gender, amongst others, are known risk factors for ceramic fractures, emphasizing the importance of preoperative risk assessment to optimize clinical outcomes [6-8].

We report a case of a 53-year-old man presenting with atraumatic right hip pain three years after a primary ceramic-on-ceramic (CoP) THR on the affected side. Radiographic evaluation revealed a fracture of the BIOLOX delta ceramic head, impacted between the femoral stem and acetabular cup, indicated for revision surgery. To our best knowledge, only three prior cases of a fractured BIOLOX delta ceramic head in primary THR with a CoP bearing have been reported, underscoring the rarity of this case [9-11].

Case Presentation

A 53-year-old man, with a body mass index of 35.83 kg/m², presented to the emergency-department (ER) with atraumatic right hip pain after experiencing a cracking sensation when placing his left foot on the bathtub rim while putting on his socks. Three years prior (2022), he had undergone a total hip replacement on the right side after being diagnosed with severe coxarthrosis. Surgery was performed by Wim Vandesande. The left side was unaffected. The operation, as well as the post-operative course were uneventful. Following implant components were used during the primary total hip arthroplasty procedure: 58 mm acetabular cup (Pinnacle Duofix Acetabular Cup, DePuy Synthes), a 32 mm cross-linked polyethylene acetabular liner (Pinnacle Marathon cross-linked polyethylene, DePuy Synthes) a collared femoral stem size 18 standard (CORAIL Total Hip System, DePuy Synthes) and a 32 mm BIOLOX delta ceramic femoral head (CeramTec, Phlochingen, Germany), + 5 mm neck length (medium). Follow-up visits were planned at two and six weeks, showing good recovery with no complications noted.

During history taking, the patient reported a sensation of walking on gravel after the incident. He also stated that he was unable to stand up again after sitting down in his couch. He denied any history of recent or prior trauma. Physical examination revealed painful hip joint mobilization, with intact sensorimotor function. No cognitive impairment was observed. There were no signs of inflammation or fever.

Based on anamnesis and clinical examination, a fracture of the prosthetic femoral head was suspected. Radiographic evaluation of the pelvis and right hip was carried out to support the working diagnosis. This showed abnormal alignment of the prosthetic femoral head and stem, with the dislocated prosthetic head impacted between the femoral stem and the acetabular cup, both of which appeared intact without any signs of failure. The remainder of the pelvic region appeared normal, except for degenerative changes in the left sacroiliac joint and lower lumbar spine. Along with the pelvic X-ray, a thoracic radiograph was performed, showing no clinical abnormalities. A standard blood work test was performed and showed no abnormalities. Due to limited experience with this type of material, revision surgery could not be performed at this hospital. Therefore, following initial first aid, the patient was transferred to hospital where the primary surgery had been carried out three years prior.

A revision surgery was performed to reconstruct the hip joint anatomy. This surgery was performed by Hans Feyen and Brecht Schuermans. The patient was placed in a supine position, and a time-out procedure was conducted. Both lower extremities were disinfected with Braunoderm (povidone-iodine/alcohol solution) from the waist down and covered with sterile drapes. The former direct anterior approach was re-utilized. Upon entering the joint space, severe fibrosis of the hip joint capsule was observed and extensively resected. Cultures were obtained from both the joint capsule and fluid, which appeared negative after microbiological examination. Opening the joint capsule revealed a multifragmented fracture of the femoral head as well as significant damage to the femoral taper and acetabular liner. Fracture fragments were carefully removed, along with the taper and liner, followed by a thorough irrigation of the hip joint. The damaged taper was initially protected with a plastic sleeve, after which a new 58 mm acetabular liner (AltrX cross-linked polyethylene, DePuy Synthes) was placed. A trial reduction was then performed using a 36 mm + 5 femoral head, which showed good joint stability. Following this, a new sleeve was placed over the femoral taper, and a definitive 36 mm BIOLOX delta ceramic femoral head (CeramTec, Phlochingen, Germany) + 5 mm neck length was implanted. The wound was irrigated copiously and closed in layers with absorbable sutures, except for the cutaneous staples. An aseptic dressing was applied.

The postoperative management included adequate pain relief and Clexane 60sc once daily over the course of 10 days. Full weight-bearing and mobilisation of the hip joint was permitted immediately. A follow-up radiograph of the patient's pelvis was performed, one day postoperatively, which showed a normal prosthesis alignment and minimal subcutaneous emphysema. Follow-up visits were scheduled at two weeks and three months, showing an uneventful recovery. Further follow-up visits were only necessary if clinically indicated.

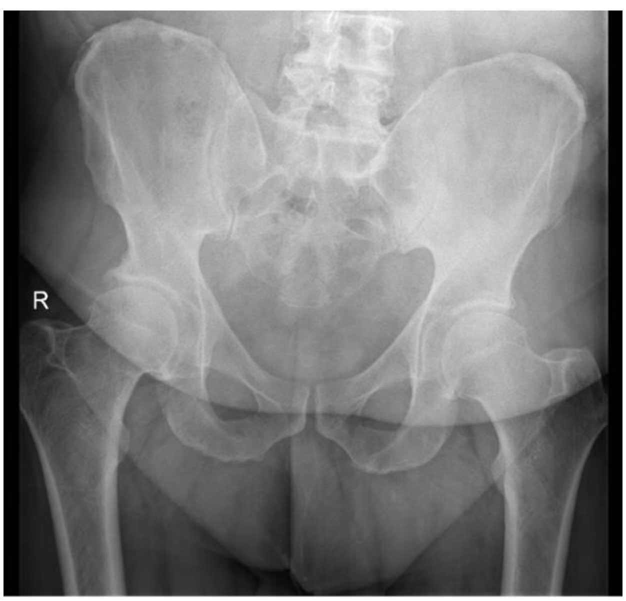

Figure 1: Pre-operative X-ray showing osteoarthritis of the right hip.

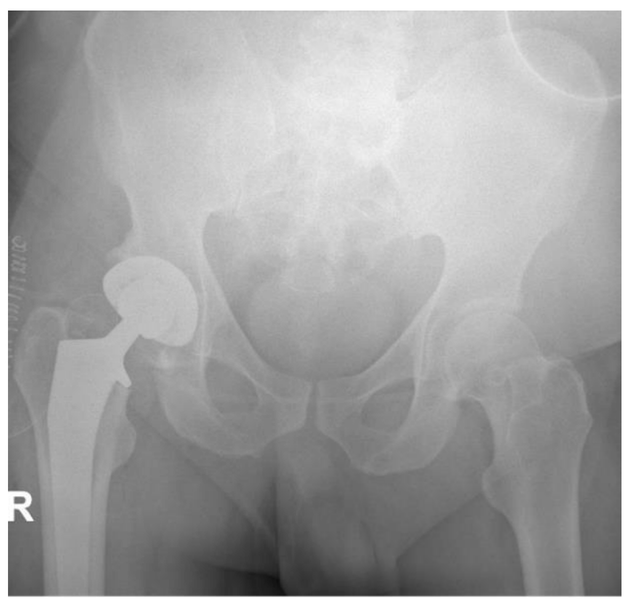

Figure 2: Post-operative X-ray after the primary THR showing the primary THR in good position.

Figure 3: X-ray at the ER department showing destruction of the femoral head.

Figure 4: Clinical photo showing the broken fragments of the failed ceramic head.

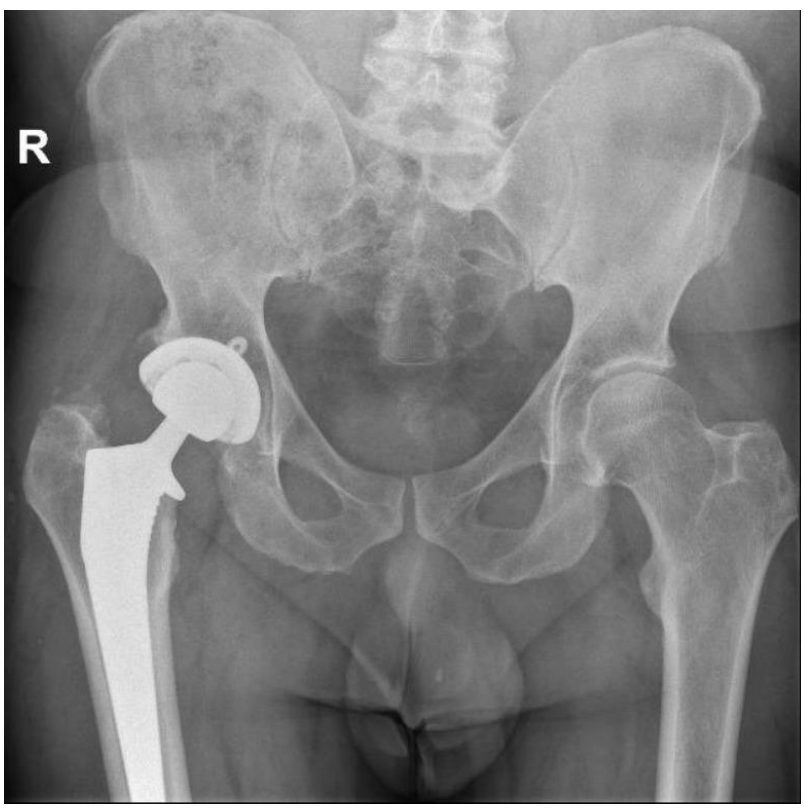

Figure 5: Post-operative X-ray showing good position of the revised THR.

Discussion

The increasing number of younger individuals, with a more demanding lifestyle, who are considered suitable candidates for THR, together with the ongoing effort to minimize polyethylene wear-induced osteolysis, have been the two major driving forces behind the development of more durable and stable implant design [1,12]. As a result, products were improved (e.g. highly cross-linked polyethylene), new bearing couples were tested (e.g. metal-on-metal, ceramic-on-ceramic), and durable materials such as ceramic components were designed [2]. Alumina ceramics, first introduced in the 1970s [3], have become increasingly popular due to their superior wear rates, low friction-coefficient, and the absence of metal ion release, unlike metal bearings. However, their brittle nature and limited tensile strength make them more susceptible to fracture [1,2].

BIOLOX delta represents the fourth generation of BIOLOX ceramics components used in THR. Its unique alumina matrix, with a grain size of less than 1.5 µm, combined with zirconia particles, chromium dioxide and strontium oxide, has demonstrated major improvements on material properties, including strength, fracture toughness, chemical and hydrothermal stability and hardness. Due to these advancements in procession technologies (e.g. isostatic pressing) and improvements in material properties, the incidence of ceramic femoral head fractures has been markedly reduced [3]. First- and second-generation ceramics showed fracture rates as high as 13.4%, whereas third generation (BIOLOX forte) and fourth generation (BIOLOX delta) ceramics demonstrated fracture rates of 0.0201% and 0.001% respectively [4,13]. Even more promising, Young-Seung et al. [6] reported no fractures of BIOLOX delta ceramic heads in a retrospective cohort study with 25 years of follow-up. Although rare, ceramic head fractures remain a feared complication leading to difficult revision surgery with high rates of repeat revision THR [5].

To the best of our knowledge, only three prior case reports have described atraumatic breakage of a BIOLOX delta ceramic femoral head in ceramic-on-polyethylene (CoP) bearings following primary THR, with occurrences ranging from three days to five years postoperatively [9-11]. Other cases of CoP bearing fractures either did not involve BIOLOX delta ceramic heads or were preceded by traumatic events. This highlights the extreme rarity of this recent case. The cause of these fractures was speculated in all three articles, all suggesting ceramic head-taper mismatch, either due to mispositioning of the head on the taper or the presence of debris at the taper, as a possible explanation [9-11]. Lee and Kim [4] support this theory, reporting taper design or mismatch being the principal cause for most of the BIOLOX delta ceramic head fractures, as a mismatch between these two components can cause extremely high stress concentrations that may ultimately lead to fracture.

Rankin et al. [14] reported a case of a 52-year-old man with a fractured 32-mm BIOLOX delta ceramic head in a primary CoP bearing, occurring nine months after the index surgery following a slip and fall one month earlier. It was believed that slow crack growth secondary to this minor trauma accounted for the delayed fracture. Due to the combined effects of mechanical stress and the disruption of the ceramic's metal-oxide bonds at the crack tip by water molecules, small initial cracks may propagate over time, eventually resulting in catastrophic fractures [15]. Duensing et al. [10] also used this theory, further proposing that the shock-absorbing and surface-contact properties of a CoP bearing couple might explain the delayed presentation of atraumatic ceramic head fractures in primary CoP arthroplasty. These mechanisms, combined with a possible head-taper mismatch, could likewise be considered relevant to our case and underscore the ongoing need to optimize current bearing couples and implant component design.

As previously described, our patient is a 53-year-old male with a BMI of 35.83 kg/m², classified as obesity type II [16]. Both his sex and his BMI represent relevant risk factors for ceramic head breakage [6-8]. Considering the male sex as a risk factor, Youn-Seung et al. [6] reported an odd ratio (OR) of 4.212 ($p = 0.004$), which is supported by Gallan et al. [7], who described an OR of 5.2 ($p < 0.001$). Regarding BMI, Howard et al. [8] stated an OR of 1.09 per unit increase ($p = 0.031$), indicating a modest yet statistically significant association between BMI and ceramic head fractures. Both these risk factors are also present in two of the earlier mentioned case reports [10,11]. These findings highlight the elevated risk in our patient.

On the other hand, according to Fang and Shang [17], CoP bearings may act as a protective factor against prosthesis fracture compared with ceramic-on-ceramic (CoC). In their meta-analysis of 15 randomized controlled trials, 28 cases of prosthesis fractures were reported, all of which occurred in the CoC group, yielding an OR of 35.768. Taken together with the previously described risk factors, these findings emphasize the importance of preoperative risk assessment to establish and individualized overall risk profile for each patient.

Rambani et al. [5] stated that revision arthroplasty for fractured ceramic bearings is susceptible to complications, mainly due to the risk of remnant ceramic fragments which can lead to abrasive third-body wear. To minimize this risk, a complete pseudocapsulectomy and synovectomy is necessary, followed by an extensive irrigation of the affected hip joint. Subsequently, all implant components should be revised, and new bearing surface selected. It is at this final step that CoP and CoC bearings are the recommended options, but no sufficient data is yet available to identify the best coupling.

Oger et al. [18] compared outcomes of revisions using CoP vs CoC bearings, analysing differences in complication rates, revision surgeries, implant survival, and functional outcomes at final follow-up. Other than significantly fewer complications in the CoP group, no statistically significant differences were observed, illustrating the inconclusiveness concerning the treatment of ceramic component fractures. Hower, the authors also noted an advantage of the CoP bearing couple: the use of CoP bearings in revision THR may embed possible remnant ceramic fragments, potentially limiting direct contact with the ceramic head and reducing the risk of abrasive third body wear.

Finally, several of these articles noted in their limitations the scarcity and underreporting of data, as well as the potential small-sample bias due to the low number of events, namely ceramic head fractures [4,8,18]. This, combined with the fact that ceramic head breakage is a serious and feared complication, underscores the need for further and more extensive research on this important topic.

Conclusion

We present a case of an atraumatic 32 mm BIOLOX delta ceramic head fracture in a CoP bearing couple, being an extremely rare but serious complication in primary THR. Despite the improvement of ceramic components, BIOLOX delta ceramic head breakage can still occur at any time, implicating the importance of assessing the risk factors and possible causes. Revision arthroplasty is a complicated treatment, with the difficulty of choosing the right revision bearing surface. More extensive research is necessary to further understand this complication for the benefit of the patient.

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