CLINICAL REPORT

Metal ions levels measurements for early total hip replacement malfunction diagnosis with “plasma-sprayed ceramic” bearings couple

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Summary  Diagnosis of total hip arthroplasty malfunction is usually based on clinical and radiographic findings, while metal ion blood levels monitoring is generally recommended for metal-on-metal bearings hip replacements. However, these measurements may be very useful in detecting anomalies in other bearing surfaces such as plasma sprayed ceramic bearings. We report on the case of a patient with a painful cementless ceramic-on-ceramic total hip prosthesis (Plasmaceram\textsuperscript{TM}) for which metal ions blood levels suggested revision surgery in the absence of any demonstrable radiographic anomaly. The high Cobalt and moderate Chromium ion levels in blood suggested a mechanical dysfunction of the bearing couple which revealed to be a severe cam effect requiring revision surgery of both components. Measurement of metal ion blood levels may play a substantial role in the assessment of a total hip prosthesis mechanism when using another bearing surface than metal-on-metal for which this measurement is usually recommended.

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Introduction

The measurement of blood metal ion levels in metal-on-metal [1–5] and ceramic-on-metal [6] hip replacements is highly advocated. It helps detect implant malfunction prior to the occurrence of radiographic anomalies [7–10]. Plasma-sprayed ceramic was introduced in the orthopaedic field in the mid 1990s, spurred on by manufacturers and the University Hospital Centre of Limoges [11,12]. Some failures were reported due to the dissociation of the ceramic coating...
Figure 1  Radiographs revealing neither bearing surface anomaly nor osteolysis around the non-cemented Plasmaceram™ bearing surface prosthesis.

from the metallic substrate thus leading to the progressive abandon of this hard-on-hard bearing which belongs to the ceramic-on-ceramic bearings [13]. Proper control of this uncommon bearing surface is challenging and provides difficulties in revision surgery indication, particularly in the absence of any radiographic anomaly and/or when clinical symptoms are limited. We report a clinical case which demonstrates the usefulness of blood levels of metal ion measurements in this type of situation.

Clinical case

Our clinical case is a 31-year-old female patient operated on for congenital dislocation of the left hip on three occasions: surgical repositioning at the age of walking, shelf arthroplasty in 1997 at the age of 19, non-cemented revision total hip arthroplasty (Saphir™, Crystal™ prosthesis, Limoges, France) made of hydroxyapatite-coated titanium alloy (Figs. 1 and 2), performed in 1998 for evolutive osteoarthritis of the hip. The 22.2 mm hard-on-hard friction type was a ceramic-on-ceramic bearing surface ((Plasmaceram™, Crystal™, Limoges, France) with a polyethylene sandwich placed between the liner and the shell (Figs. 1 and 2). The Plasmaceram™ is a plasma sprayed hexaplasma ceramic combining chromic oxide and tungsten carbide on a titanium substrate (22.2 mm head and metal liner placed in the acetabular polyethylene sandwich). In 2004, the patient underwent a contralateral total hip arthroplasty (right hip) using a hard-on-hard bearing surface made of alumina.

Figure 2  Appearance of the explants, the black arrow shows the osseo-integration process on the cup (a). The white arrows show the cam effect and its extent in the postero-inferior region of the cup (the white arrow on the right shows the contact between the neck and the border of the Plasmaceram™) (b). However, the prosthetic neck does not reveal any contact mark (c).
cemented (non-cemented prosthesis featuring a titanium alloy stem and acetabular cup) which was satisfactory both clinically and radiographically. The patient was referred to us in 2007 for a 5-year inguinal and crural pain in her left total hip prosthesis. Pain had been moderate for 3 years and severe for the last 2 years. She had visited several surgeons, none of whom had suggested a revision surgery, in the absence of any radiographic anomaly (Fig. 1). While she was referred to our department, pain became more severe requiring the need for a 3-month sick leave. Occasionally, she reported abnormal noises (squeaking) occurring after prolonged walking or sexual intercourses. The Merle d’Aubigné score [14] was 14 (pain 4; mobility 5; walking 5).

At clinical examination, neither axial piston, nor cam effect were detected during maximum hip range of motion, particularly in maximum flexion combined with internal rotation and in extension combined with external rotation. However, the patient reported a long-lasting stiffness from childhood, aggravated by the different surgeries she had undergone, the left hip mobility being measured as followed: 85/10 30/20 30/20.

Radiographic examination did not give evidence of any osteolysis process (Fig. 1). A CT-scan protocol [15] demonstrated good cup positioning and over-anteversion of the femoral stem (40° of femoral anteverision, 15° of acetabular anteverision). A citrine liquid was obtained from hip puncture and did not reveal any severe metallosis and was sterile in standard and enriched Rosenow samples [16]. No measurement of metal ion levels was performed from the articular liquid. Therefore, it appeared to be a painful arthroplasty without any evidence of the failure origin but suspicion of a malfunctioning of the bearing surface. The measurement of blood metal ion levels was decisive for surgery indication: cobalt 9.7 μg/L, chromium 0.8 μg/L and titanium < 5 μg/L. The cobalt blood level was 10 times greater than the normal laboratory value whereas the chromium concentration was moderately increased but inferior to the normal value in the absence of exposure (< 1 μg/L), the titanium blood level was under the threshold of detection (Claude Levy Biomnis Laboratory, Évry). Apart from her contralateral non-cemented prosthesis featuring a titanium alloy ceramic (non-cemented prosthesis featuring a titanium alloy stem and acetabular cup) which was satisfactory both clinically and radiographically. The patient was referred to us in 2007 for a 5-year inguinal and crural pain in her left total hip prosthesis. Pain had been moderate for 3 years and severe for the last 2 years. She had visited several surgeons, none of whom had suggested a revision surgery, in the absence of any radiographic anomaly (Fig. 1). While she was referred to our department, pain became more severe requiring the need for a 3-month sick leave. Occasionally, she reported abnormal noises (squeaking) occurring after prolonged walking or sexual intercourses. The Merle d’Aubigné score [14] was 14 (pain 4; mobility 5; walking 5).

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Discussion

The use of a hard-on-hard bearing couple leads to implant malfunctions which might be attributable to several anomalies: misalignment of the prosthetic components (cam effect, fracture of implant due to a cam effect, eccentric load and early wear), defect in the design of the implants (early osteolysis, abnormal noises, early wear) [10,17–20]. In our study, the cam effect was responsible for pain and could have been clinically identified since the CT scan reported an excessive femoral anteversion compensated by a small acetabular anteversion [15]. The stiffness of the hip did not suggest a cam effect and did probably interfere with proper clinical detection [10].

According to our observation, hard-on-hard bearing surfaces, commonly recommended in young people [21–23], should be cautiously used: precise selection of surgical indications and materials, proper implants alignment and thorough monitoring [22,24]. The Plasmaceram™ bearing surface did not comply with all these requirements and, as far as we know, its failures were not published in PubMed, but reported in an electronically accessible article [13]. Therefore, the lack of implant knowledge, the moderate symptoms and above all the lack of radiographic evidences, were confounding factors which did not encourage revision surgery. Conversely, measurement of metal ion levels suggested the need for revision surgery. The increase in Cobalt ion release appears paradoxical since Plasmaceram™ was theoretically made of Chromium and Tungsten, but some foreign metal particles may have induced this result since anomalies in the quality control protocol had been identified during the manufacturing process [13].

Figure 3 Radiograph obtained after bipolar revision using a large diameter metal-on-metal bearing surface (hybrid arthroplasty featuring an un cemented femoral component and a cemented reinforcement acetabular implant).
The measurement of whole blood, erythrocyte and serum metal ion levels imposes quality requirements: The use of specific needles without chromium, cobalt nor titanium, puncture point free from any other veinous structure, sample storage at regulated temperature prior to analysis, transportation in a specific kit, specialized laboratory entitled to conduct an Inductively Coupled Plasma Mass Spectroscopy (ICPMS) analysis for Cobalt and ICP-AAS for chromium and which threshold values should be known (usually 0.1 μg/l for cobalt and 0.5 μg/l for chromium) [3,25]. In metal-on-metal bearings, measurement of metal ion levels should help detect any mechanical anomaly and promote revision indication [8—10]. In hard-on-hard bearings, measurement of metal ion levels might reveal a fixation anomaly [26]. On the other hand, in other hard-on-hard bearings, particularly ceramic bearings, these measurements are rarely performed: Grubl et al. [27] have studied the alumina, chromium and cobalt rate by comparing non-cemented ceramic-on-ceramic with metal-on-metal prostheses and did not observe any increase in the absence of major dysfunction. If the measurements of blood metal ion levels help detect metal-on-metal bearing dysfunctions [8,9], they might also be confusing as demonstrated in Lhotka et al. study [28] who did not identify any increase in ion levels when using the Sikomet™ bearing surface (at 4-year follow-up) even though this bearing couple has demonstrated unusually frequent failures with metallosis and osteolysis [18,24]. On the other hand, according to Langton et al. [9] and De Hann et al. [8] an increase in blood metal ion levels in resurfacing arthroplasties, could reflect a malpositioning and especially a major cup inclination, inducing an eccentric wear or an excessive anteversion and leading to instability and cam effect.

According to our observation, the follow-up information is of great interest regarding implants which early failures [29] are induced by manufacturing defects such as the Plasmaceram™, and should be published in order to prevent recurrence of these errors by informing the orthopaedic community which could have to face the revision surgery of this type of implant [29]. Following the Plasmaceram™ encouraging results at 2 years [12], a publication in a non-referenced review on PubMed by Arnaud et al. [13] reported 20% of failures at only 4-year follow-up, particularly due to the thin ceramic coating removal. These data which are available online [13] in the French language need be readjusted and should be made more accessible in the databases.

Conclusion

Measurement of blood metal ion levels should help to better understand implant bearing surface dysfunctions when using another bearing surface than metal-on-metal for which this measurement is usually recommended.

Conflicts of interest

None.

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Metal ions levels measurements to indicate revision of total hip replacement