Excessive Anteversion Leads to Failure at 3 Years Due to Impingement as Evidenced by Twin Notches in Ti6A4V Stem

Donaldson T¹, Burgett-Moreno M¹, Clarke I¹

Abstract

A 63-year old female with bilateral hip replacements was referred to our clinic for pain and elevated metal ions. Her left hip had been revised earlier. The right hip had an SROM Ti6Al4V stem implanted with a 28mm head, a 28mm CoCr liner and Pinnacle Ti6Al4V shell. The patient reported pain, numbness, tingling, and repeated clicking and popping sensations with gait. She specifically noted that her hip would freeze while walking and could pop rising from a chair. Repeated metal ion levels showed Co (blood) 17ppb, Cr (serum) 21ppb, and Ti (blood) at 69ppb. CT-images of right hip revealed femoral stem anteversion was 43° and cup anteversion was 40°, for a combined anteversion of 83°. The right hip was revised 3.5 years postoperatively for persistent pain and elevated metal ions. At surgery, large twin notches were evident on her posterior femoral neck and 10mm-wide scalloped damage was evident in the rim of the Ti6Al4V shell. SEM-imaging revealed contaminating layers on CoCr head containing elements Al, V and Ti. These indicated that titanium-alloy particles liberated by cup-to-neck impingements had transferred to the CoCr bearings. Our intent in this case was not to document that a MOM bearing produced impingement damage, because this case clearly implicated adverse surgical positioning. Rather, the intent was to document sequelae likely in a THA case that has a metal cup impinging on a metal femoral neck. In particular, twin notches on the femoral neck indicated that this patient was routinely impinging her Ti6Al4V shell against the Ti6Al4V neck and also subluxing her femoral head out of the cup. These signs are a clear indication that one or both components must be revised, as opposed to simply replacing the CoCr liner with a revision polyethylene liner.

Keywords: S-ROM, metal-on-metal, impingement, notches, total hip

Level of Evidence: AAOS Therapeutic Level IV

Introduction

Impingement in 28mm THA may be a common pathway to failure [1-7]. In support, metal-on-polyethylene (MPE) bearings have shown impingement damage in 45-65% of cases [3, 8-10]. Likewise, a recent retrieval study of ceramic-on-ceramic (COC) retrievals noted impinge-

¹ Donaldson Arthritis Research Foundation, 900 E. Washington Street, Suite 200 Colton, CA 92324 US

© 2015 Donaldson, Burgett-Moreno, Clarke. All rights reserved. Authors retain copyright and grant the journal right of first publication with the work. Reconstructive Review follows the [Creative Commons Attribution-NonCommercial CC BY-NC](#). This license allows anyone to download works, build upon the material, and share them with others for non-commercial purposes as long as they credit the senior author, Reconstructive Review, and the Joint Implant Surgery & Research Foundation (JISRF). An example credit would be: "Courtesy of (senior author's name), Reconstructive Review, JISRF, Chagrin Falls, Ohio".

ment occurred in 83% of 28mm and 32mm COC retrievals [11] and a recent metal-on-metal retrieval study indicated that 96% of large-diameter metal-on-metal (MOM) retrievals showed evidence of impingement [12]. One of the sequelae to routine impingement of a total hip arthroplasty (THA) can be rim damage to the acetabular cup and notching damage of the femoral neck [19-22]. If carried over hundreds of thousands of gait cycles as a result of repetitive sub-clinical subluxation (RSS) [13-15], considerable damage can result. The fact that COC and MOM retrievals showed such consistent impingement damage is not by itself proof that such led to revision. Nevertheless, such evidence may indicate why some 28mm MOM cases showed good results over 7-15 years and others showed lesser success [16-18].

Consent

The patient signed an IRB approved consent allowing review of her records and analysis of her hardware as well as verbally consented to publication of her case.

Case Report

A 63 year old female with bilateral hip replacements was referred to our clinic 3 years after her right primary THA for pain and elevated metal ions. An S-ROM femoral stem had been implanted with a 28mm S-ROM femoral head and 28mm Pinnacle cup (Depuy, Warsaw, IN). The patient reported pain, numbness, tingling, and repeated clicking and popping sensations with ambulation. She specifically noted that the hip would freeze up during strides while walking and pop when rising from a chair. Additionally, the referring physician reported metal ion concentrations (blood) with Co and Cr ion levels of 6.4ppb and 38.9ppb, respectively. Metal ion levels were repeated and Co (blood) was 16.7ppb, Cr (serum) was 21.4ppb, and Ti (blood) was 69ppb. Radiographic analysis at 3 years demonstrated normal bilateral hip replacements with S-ROM stems (Figure 1). It was noted that the left hip was a metal-on-polyethylene with significant anteversion, and therefore, was revised first. CT images of the right hip confirmed that both the femoral stem was 43° anteverted and the acetabular cup was 40° anteverted, giving a combined anteversion of 83°. This resulted in very limited external-rotation and extension of the femoral component.

The right hip was revised 3.5 years postoperatively for persistent pain and elevated metal ions. At surgery, the patient had a significant collection of dark synovial fluid as well as a large amount of black synovial lining throughout the acetabulum, over the greater trochanter, and posterior

Figure 1: AP Pelvis radiograph with left hip 56° cup inclination and right hip 44° cup inclination.

bursal sack. The large twin notches were clearly evident on the posterior femoral neck during surgery.

Retrieval Analysis

The retrieved components were cleaned using a standard, non-destructive process, then inspected visually and by stereomicroscopy to define the main wear zone areas (MWZ), cup rim breakout wear, and stripe damage [12].

Twin notches were observed on the femoral stem with the proximal notch and distal notch measuring 4.5mm and 2.5mm wide, respectively (Figure 2a). SEM imaging showed a raised peak between the two notches as well as a slight variation in measured width of the notches (Figure 2b). On the cup, a cosmetic blemish was noted on the CoCr

Figure 2: a) Photograph of S-ROM® stem with twin notches on posterior side of stem b) SEM image of twin notches.

Figure 3: Photograph of (1) cosmetic blemish of the CoCr liner rim and (2) scallop in Ti6Al4V shell rim, evidence of impingement with the femoral neck.

rim and more conspicuously a 10mm long deformity in the rim of the Ti6Al4V shell was identified (Figure 3). SEM imaging (EVO MA15, Zeiss) of the Ti6Al4V shell rim revealed a scalloped portion of the rim bevel (Figure 4).

Suspecting cup rim impingement, the contours of the CoCr liner and Ti6Al4V shell rims were replicated using a silicon agent (Aquasil-LVTM, Densply, Milford DE) and analyzed by SEM. The inner and outer cup rims spanned 4.2mm and 3.1mm, respectively (Figure 5). These proved to be a good match with the twin notches on the femoral neck. As detailed by white light interferometry (WLI: NewView600, Zygo Inc) the notches were cut 0.5 to 0.8mm deep in the S-ROM neck (Figure 5). Additionally, SEM imaging of stripe wear on the femoral head revealed contaminating surface layers of metal measuring 2µm thick (Figure 6) and were identified by EDS imaging (Bruker) as containing elements titanium, aluminum, and vanadium, indicative of titanium alloy and most likely the result of repetitive cup-to-neck impingement with release of metal particles.

Both the femoral head and cup presented with virtually circular wear areas. The femoral head had several polar stripes across the superior MWZ and basal stripes outside

Figure 4: SEM image of scalloped Ti6Al4V shell rim.

Figure 5: Replicated rims of Pinnacle Ti6Al4V shell and Ultamet CoCr liner represented a good match to the twin notches on the S-ROM femoral neck.

Figure 6: a) SEM image of titanium transfer onto CoCr head b) WLI image of titanium transfer on CoCr head measuring 2µm.

Figure 7: CoCr femoral head with polar stripes and basal stripes demarcated and measured according to the polar axis (P).

the MWZ. Polar stripe angles were measured with reference to the polar axis (P) and revealed an approximate 20° variance between points of impingement (Figure 7).

Discussion

The intent of this study was not to document that a MOM bearing can produce impingement damage, because this case clearly implicated adverse surgical positioning. Rather, the intent was to document sequelae likely in any THA case that has a metal cup impinging on a metal femoral neck (Table 1).

ID	Damage Evidence	Site	Causation	Involvement	Sequellae
1	Twin notches	Neck	impingement	liner + shell	Ti6Al4V, CoCr particles
2	Twin defects	Cup	impingement	liner + shell	Ti6Al4V, CoCr particles
3	Main wear zone	Head	asymmetric	restricted in extension	Modified gait pattern
4	Metal transfer	Head	metal debris	Contaminated bearing	Ti6Al4V debris
5	Polar stripes, head	Head	terminal motion	head, liner	CoCr particles
6	Basal stripes	Head	terminal motion	head, liner	CoCr particles
7	Multiple notches, stripes	Head	Subluxation	Head levered out of cup	Cup edge-wear

Table 1. Consequences due to CoCr liner and Ti6Al4V shell impingement against Ti6Al4V femoral neck.

Neck-notching case reports are relatively few even in 28mm THA [2, 5, 19-21, 23]. Impingement in this case did little damage to the CoCr liner, produced a fairly mild scalloping in the Ti6Al4V shell rim, but did produce major wear damage to the Ti6Al4V femoral neck. Impingement against a titanium alloy implant is known to produce more damage than with a CoCr implant [23], resulting in release of large particles of titanium alloy known to create adverse MOM wear [24, 25]. The positioning of polar stripes and the evidence of twin neck notches was further indication that not only was impingement present, but the femoral head was subluxing out of the cup (Table 1). We have documented this in other case reports and shown that head subluxation produces edge-wear in the cup rim [12, 22-23]. The damaged rim of the Ti6Al4V acetabular shell was recessed approximately 0.1mm below the face of the Ultamet CoCr liner. This highlighted the fact that the femoral neck impinged first on the rim of the CoCr liner. Thus, once the head subluxed 10° out of the cup, the Ti6Al4V neck was able to pivot and wear on the rim of the Ti6Al4V shell. Our priority in this case was to revise a 28mm MOM bearing to a ceramic-on-polyethylene construct. In consequence, this patient experienced multiple dislocation problems and two more revisions. Thus twin notches on the femoral neck may be considered a clear indication of head-subluxation and dislocation risk with attendant adverse wear conditions, indicating a need to revise one or both components.

It is our opinion that impingement is commonplace, unpredictable, and impossible to guard against. Commonplace examples are the blackened surfaces on ceramic balls, typically containing Ti, Al and V elements representing contamination by Ti6Al4V particulates (Figure 8). If the stem is revised with the MOM bearing there can be evidence of circumferential damage created by cup impingement, typically cosmetic blemishes on CoCr necks but actual notching in Ti6Al4V necks. On the femoral head there will most likely be evidence of polar stripe damage created by the cup rim at the terminal positions of various functional activities.

References

1. R.L. Barrack, T.P. Schmalzried, Impingement and rim wear associated with early osteolysis after a total hip replacement : a case report, *J Bone Joint Surg Am*, 84-A (2002) 1218-1220.
2. D. Gambera, S. Carta, E. Crainz, M. Fortina, P. Maniscalco, P. Ferrata, Metallosis due to impingement between the socket and the femoral head in a total hip prosthesis. A case report, *Acta Biomed Ateneo Parmense*, 73 (2002) 85-91.
3. M. Yamaguchi, T. Akisue, T.W. Bauer, Y. Hashimoto, The spatial location of impingement in total hip arthroplasty, *J Arthroplasty*, 15 (2000) 305-313.

Figure 8: Consequences due to CoCr liners and Ti6Al4V shells impinging against either CoCr or Ti6Al4V femoral necks. Circumferential marks of impingement can be notches in Ti6Al4V necks and cosmetic blemishes in CoCr necks (arrows).

4. M. Earll, T. Fehring, W.L. Griffin, J.B. Mason, T.H. McCoy, Early osteolysis associated with trunion-liner impingement, *Clin Orthop*, (2004) 153-156.
5. K. Onda, S. Nagoya, M. Kaya, T. Yamashita, Cup-neck impingement due to the malposition of the implant as a possible mechanism for metallosis in metal-on-metal total hip arthroplasty, *Orthopedics*, 31 (2008) 396.
6. M. Manaka, I.C. Clarke, A. Gustafson, A. Imakiire, Impingement in Ceramic Hip Patient: A retrieval and Wear-Scar Analysis of Femoral Head., *Key Eng. Mater.*, 240-242 (2003) 847-848.
7. F. Randelli, L. Banci, A. D'Anna, O. Visentin, G. Randelli, Cementless Metasul metal-on-metal total hip arthroplasties at 13 years, *Journal of Arthroplasty*, 27 (2012) 186 - 192.
8. M. Kligman, B.D. Furman, D.E. Padgett, T.M. Wright, Impingement contributes to backside wear and screw-metallic shell fretting in modular acetabular cups, *J Arthroplasty*, 22 (2007) 258-264.
9. W.Y. Shon, T. Baldini, M.G. Peterson, T.M. Wright, E.A. Salvati, Impingement in total hip arthroplasty a study of retrieved acetabular components, *J Arthroplasty*, 20 (2005) 427-435.
10. R.M. Hall, P. Siney, A. Unsworth, B.M. Wroblewski, Prevalence of impingement in explanted Charnley acetabular components, *J Orthop Sci*, 3 (1998) 204-208.
11. C.I. Esposito, W.L. Walter, A. Roques, M.A. Tuke, B.A. Zicat, W.R. Walsh, W.K. Walter, Wear in alumina-on-alumina ceramic bearings. A retrieval analysis of edge loading, *J Bone Joint Surg Am*, 7 (2012) 901-907.
12. I.C. Clarke, T.K. Donaldson, M.D. Burgett, E.J. Smith, J. Bowsher, C. Savisaar, A. John, J.Y. Lazennec, E. McPherson, C.L. Peters, Normal and Adverse Wear Patterns Created In-vivo on MOM Surfaces - a retrieval study representing four vendors, in: S.M. Kurtz, S.A. Greenwald, W.M. Mihalko, J.A. Lemons (Eds.) *ASTM Symposium on Metal-on-Metal Total Hip Replacement Devices*, ASTM International, West Conshohocken, PA, 2013 pp. 157-192.
13. E.J. McPherson, I.C. Clarke, T.K. Donaldson, M.D. Burgett, A MOM dislocator case demonstrating importance of impingement damage in triggering adverse 3rd-body abrasive wear risks, in: *Orthopedics Today*, Jan 13 - 16, Hawaii, 2013.
14. E.J. McPherson, I.C. Clarke, T.K. Donaldson, Lesson learned from retrieval analysis of a dislocating, large diameter MoM revision THA - A case report, *Reconstructive Review*, 2 (2012) 10 - 14.
15. E. McPherson, C. Peters, Correction of Femoral Acetabular Impingement at the Time of Primary Large Diameter Metal-Metal THA, in: *AAOS New Orleans, LA*, 2010.
16. K. Bjorgul, W.N. Novicoff, S.T. Andersen, O.R. Ahlund, A. Bunes, M. Wiig, K. Brevig, High rate of revision and a high incidence of radiolucent lines around Metasul metal-on-metal total hip replacements, *Bone Joint J*, 95-B (2013).
17. V. Eswaramoorthy, P. Moonot, Y. Kalairajah, L.C. Biant, R.E. Field, The Metasul metal-on-metal articulation in primary total hip replacement: clinical and radiological results at ten years, *J Bone Joint Surg Br*, 90 (2008) 1278-1283.
18. J.Y. Lazennec, P. Boyer, J. Poupon, M.A. Rousseau, C. Roy, P. Ravaud, Y. Catonne, Outcome and serum ion determination up to 11 years after implantation of a cemented metal-on-metal hip prosthesis, *Acta Orthop*, 80 (2009) 168-173.
19. H. Iida, E. Kaneda, H. Takada, K. Uchida, K. Kawanabe, T. Nakamura, Metallosis due to impingement between the socket and the femoral neck in a metal-on-metal bearing total hip prosthesis. A case report, *J Bone Joint Surg Am*, 81 (1999) 400-403.
20. A. McMurtre, R. Abhijit, A.R. Guha, J.R. Wootton, Loose Metasul liner causing partial amputation of the neck of the femoral component, *Journal of Arthroplasty*, 24 (2009) 159.e151 - 153.
21. A. Malik, L.D. Dorr, W.T. Long, Impingement as a mechanism of dissociation of a metasul metal-on-metal liner, *J Arthroplasty*, 24 (2009) 323 e313-326.
22. T.H. Eickmann, I.C. Clarke, A. Gustafson, Squeaking in a ceramic on ceramic total hip, in: H. Zippel, M. Dietrich (Eds.) *Bioceramics in Joint Arthroplasty*, Steinkopff Verlag, Darmstadt, Berlin, Germany, 2003, pp. 187 - 192.
23. Clarke I C, Lazennec J Y, Brussen A, Savisaar C, Bowsher J G, Burgett M, et al. Risk of Impingement and Third-body Abrasion With 28-mm Metal-on-metal Bearings. *Clin Orthop Relat Res* 2014; 472 (2): 497-508.
24. Halim T, Burgett M, Donaldson TK, et al. Profiling the third-body wear damage produced in CoCr surfaces by bone cement, CoCr, and Ti6Al4V debris: a 10-cycle metal-on-metal simulator test. *Proc Inst Mech Eng H* 2014;228:703-713.
25. Halim T, Clarke I C, Burgett-Moreno M, Donaldson T, Savisaar C, Bowsher J. A simulator study of adverse wear with metal and cement debris contamination in metal-on-metal hip bearings. *Bone Joint Res* 2015;4:29-37.