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Case Report

Disassociation of a Cold-Welded Bimodular Titanium Femoral Stem by Intraoperative Ice Cooling

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ABSTRACT

Modularity in total hip arthroplasty allows a surgeon to have intraoperative versatility, allowing for fine adjustments of the femoral offset, leg length, and version. However, modularity can be a source of multiple complications. This case report describes a novel intraoperative solution for the problem of cold welding of a neck-stem junction using sterile ice to cryogenically disengage the modular components.

Introduction

Modularity in total hip arthroplasty (THA) is a useful tool that allows surgeon intraoperative versatility. It is particularly useful in dysplastic hips, in anatomic variants, or in the revision setting. It allows for fine adjustments and calibration of the femoral offset, leg length, and version, independently from femoral stem placement in the femoral canal [1,2]. This allows for a more anatomic positioning of implants specific to the patient and may help reduce wear and improve longevity of the implant [3]. However, the addition of modularity is not without complications. Increasing the number of tapered junctions allows for more opportunity to introduce fretting, corrosion, local adverse reaction to particulate debris, dislocations, neck fatigue fracture, and cold welding of the modular neck-stem interface to occur [2].

There is extensive literature on modular neck fatigue fracture associated with micromotion, corrosion, and fretting [2,4-11]. There is also significant coverage in the literature on local adverse reaction to debris caused by corrosion and fretting between a modular neck and stem [1,12-19].

There is a paucity in the literature, however, regarding clinical cold welding of modular neck-stem interfaces and intraoperative techniques to address this. It has been reported that irreversible cold welding of the modular neck and stem interface can occur and result in failure to disengage during a revision THA [20-24]. However, there appear to be no reported intraoperative solutions for this aside from removing the entire neck and stem as a single unit. This case report discusses a novel intraoperative solution to a cold-welded titanium modular neck to a well-fixed titanium stem in a revision THA performed for trauma.

Case history

This patient is a 72-year-old male who was involved in a motorcycle crash at highway speeds, sustaining multiple injuries. These injuries included a right periprosthetic hip dislocation and disassociation of the femoral head from the modular neck along with a comminuted left distal femoral periprosthetic supracondylar femur fracture (Fig. 1a and b; Fig. 2a and b). He has a history of a right THA and bilateral total knee arthroplasties (TKAs) at an outside hospital many years before his presentation. This case report focuses on the right hip injury and revision surgery.

Preoperative radiographs of the right hip showed evidence of well-fixed cementless implants on both the femoral and acetabular sides. Radiographically and clinically, the hip appeared to be dislocated posteriorly with disassociation of a cobalt-chrome head

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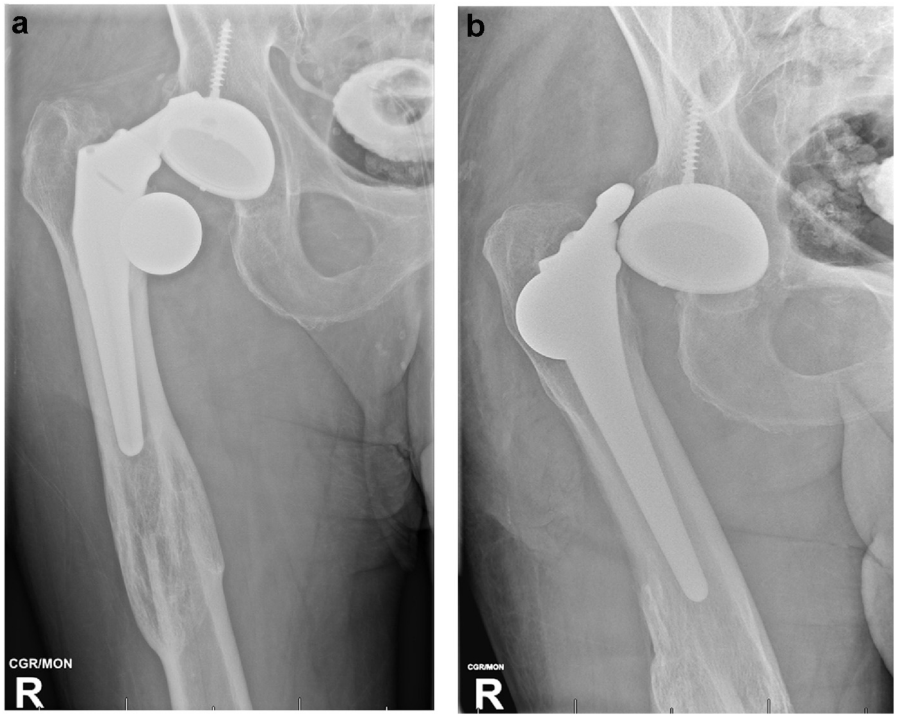

Figure 1. Preoperative anteroposterior radiograph (a) and attempted lateral radiograph (b) of the right hip showing right periprosthetic hip dislocation and disassociation of the femoral head from the modular neck.

from the titanium neck. The neck on plain radiographs showed notching of the proximal inferior portion of the taper junction (Fig. 3a). The implant was identified as a Zimmer M/L Taper Kinectiv titanium bimodular femoral component (Zimmer M/L Taper Hip Prosthesis with Kinectiv Technology, ZimmerBiomet, Warsaw, IN) with a titanium modular neck. Three-dimensional imaging was obtained because of the polytraumatic nature of the patient's presentation and to rule out an ipsilateral periprosthetic fracture. This confirmed no fracture and demonstrated, with more clarity, the damage to the trunnion (Fig. 3b).

The arthroplasty service was consulted for operative management of his multiply injured lower extremities. He was indicated for revision right THA and revision left TKA in the form of a distal femoral replacing hinged knee prosthesis. Informed consent was obtained from the patient, and all questions and concerns were thoroughly addressed. He was cleared for revision arthroplasty and

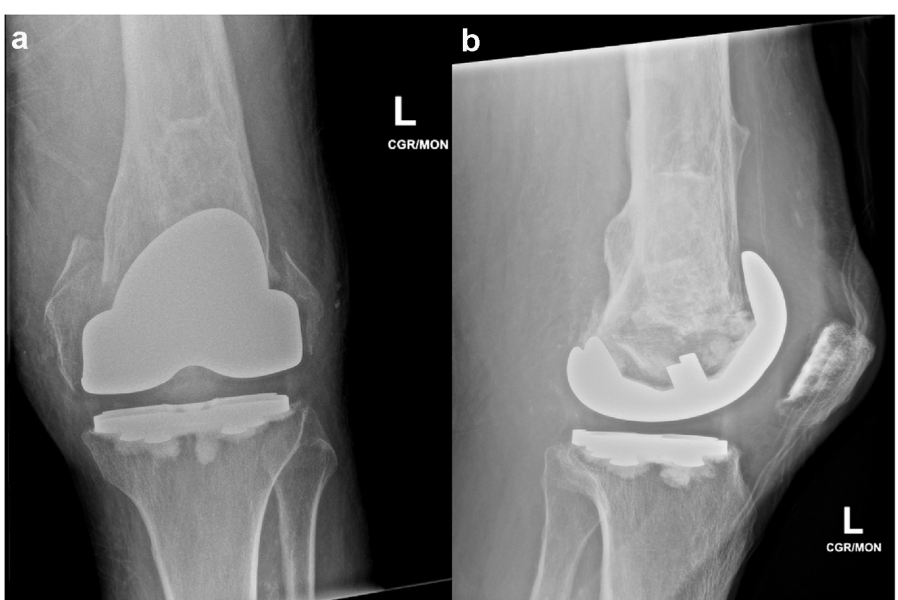

Figure 2. Preoperative anteroposterior radiograph (a) and lateral radiograph (b) of the left knee demonstrating a comminuted left distal femoral periprosthetic supracondylar femur fracture.

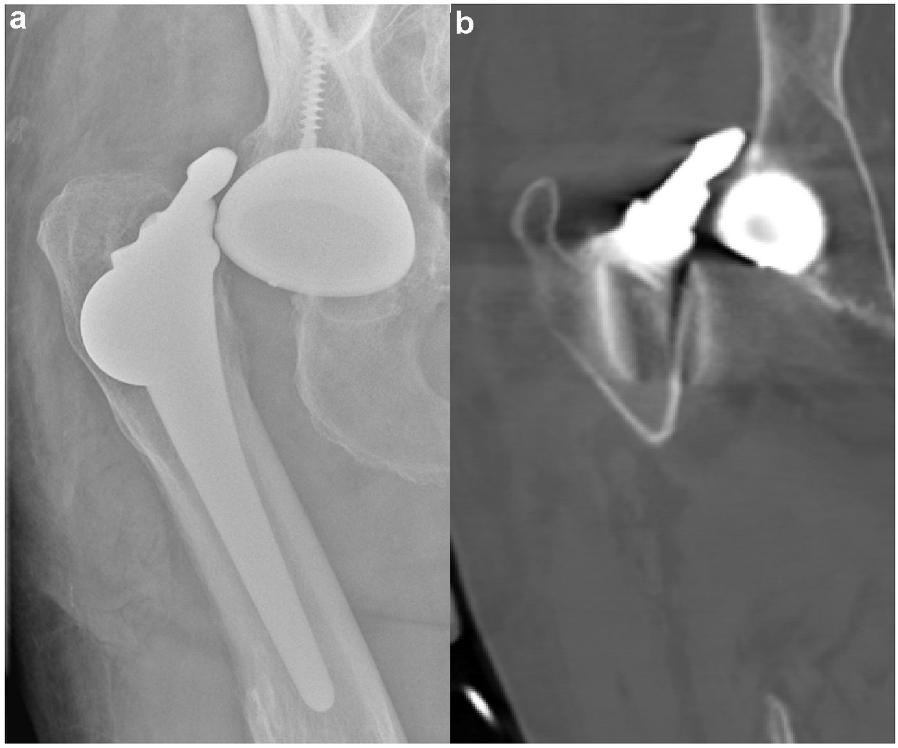

Figure 3. (a) Radiograph of the right hip demonstrating notching of the proximal inferior portion of the taper junction. (b) Computed tomography scan of the right hip redemonstrating notching of the taper junction.

was taken to the operating theater. After induction of general anesthesia, the patient was positioned supine on a radiolucent flattop bed, and the hip and knee were prepped and draped. Supine positioning allowed for access to both extremities without repositioning the patient. It also allowed access to the hip through a direct anterior approach and avoidance of the large posterolateral Morel-Lavallée lesion, which was found directly over and posterior to his prior posterior approach incision.

A modified Smith Peterson approach to the hip was performed. An anterior capsulotomy was performed, and on entering the joint, a rush of dark black fluid was encountered as was a great deal of black-stained adverse local soft-tissue reaction consistent with metallosis. This was not unexpected, given the amount of damage to the trunnion seen on preoperative imaging. A thorough debridement of this tissue was performed until a negligible amount of metallic staining was visible. Inspection of the stem revealed a well-fixed femoral component. Inspection of the modular neck was notable for a grossly damaged trunnion at the head-neck interface, with a great deal of notching and rounding consistent with mechanically assisted crevice corrosion (MACC) and subsequent macroscopic trunnion loss. The femur was then exposed and positioned for modular neck removal. Removal of the neck was attempted using a proprietary femoral neck removal backslap from the implant manufacturer, which was unsuccessful. We then proceeded to try a much more powerful universal extraction system, but the modular neck showed no signs of movement. Significant effort and force were applied to both extraction devices, and both were unsuccessful. The neck appeared to be clinically cold welded to the stem.

Neck retention was unacceptable with the degree of trunnion damage witnessed. Options at this point were en bloc removal of the stem likely requiring an anterior-based femoral osteotomy or further attempt at removal of the modular neck with subsequent replacement of a new titanium neck and a new ceramic femoral head. Removal of the femoral stem would have added significant operative time and morbidity to a multiply injured and physiologically compromised patient. We decided to attempt one more alternative strategy for neck removal; using knowledge of thermoregulation and experience with mechanical engineering principles of shrink-fitting metals and thermal separation, we used sterile ice to cool the neck relative to the stem in hopes of contracting the metal for neck removal. The sterile ice comes in the form of frozen intravenous (IV) bags of sterile saline that are typically used in cardiac and transplant cases (Fig. 4a). We cut open the IV bag and broke the large ice block down into manageable sizes that could be fit easily circumferentially around the neck (Fig. 4b). This relatively rudimentary means of cooling is routinely used in thermoregulation during cardiac cases.

After 10 minutes of cooling the trunnion, we again attempted to remove the neck with the universal extraction system, and we found the neck to come out easily with 3 moderately forceful blows, a noticeable difference from the previous attempt. We inspected the female morse taper junction in the stem; there was no obvious macroscopic damage of the morse taper thread topography and no signs of metal debris, deformation, or corrosion. The male portion of this taper on the modular neck also appeared pristine without any discoloration or obvious damage. The femoral stem remained well fixed. Attention was then turned to the polyethylene liner that was exchanged. Interrogation of the acetabular component was unremarkable, and the component was retained as it was well fixed and reasonably well positioned on preoperative films. The head that had disassociated from the femoral stem was removed from the posterior thigh through the dislocation tract created through the disrupted posterior capsule. A small lateral accessory incision was used through which uterine forceps were inserted and used to lever the dislocated head cranial and anterior so that it could be grasped and removed through the anterior hip incision. We then placed a new titanium modular femoral neck of the same size and

Figure 4. (a) Frozen sterile bag of normal saline. Bag cut and ice broken into pieces and placed around the modular neck, cryogenically separating the modular neck and stem junction. (b) The ice block broken down into manageable sizes that could be fit easily circumferentially around the neck.

placed a ceramic femoral head of the same length. The hip was reduced, taken through a full range of motion, and found to be very stable.

Although bimodular hip implants historically have had a poor track record, this particular stem has not been recalled, and modular titanium neck implants were available and ready for this case. While there have been a number of case reports of MACC at the head-neck junction of this specific 12/14 taper when used with cobalt-chromium heads, there has only been a single case report of possible MACC at the titanium-titanium stem-neck taper junction with this stem [25]. In this one case report, the presumed crevice corrosion seen was the black corrosion product seen on the modular neck at the neck-stem interface near the exposed shoulder of the neck, while the patient had obvious MACC at the head-neck junction with black corrosion products all around that male taper along with elevated cobalt and chromium ion levels while having undetectable titanium ion levels. Therefore, this stem has minimal risk for MACC at the neck-stem trunnion. Furthermore, when the titanium neck is coupled with a ceramic head, retention of this particular stem is a reasonable option in a complicated clinical scenario such as this one. However, we would be remiss to not also mention the fact that there have been several case reports in the literature of fracture of modular titanium femoral necks. Although the risk of MACC at the neck-stem junction may be lessened with these titanium femoral necks, this does not come without this slight added risk of fracture [6,10,11,26]. In this complicated 72-year-old patient with polytrauma, it was felt to be appropriate to place a new titanium neck with the same length and offset as the removed component and a new 40 ceramic head of the same length (Fig. 5a and b). Stability was found to be excellent with this construct in place. The wounds were copiously irrigated and were closed in a layered fashion. We then proceeded to address his contralateral distal femur and performed a revision TKA with a distal femoral replacing hinge in this same setting (Fig. 6a and b). The patient tolerated the procedure well and began standing and ambulating with physical therapy while in the hospital as he was allowed to be weight-bearing as tolerated on his bilateral lower extremities. The patient was seen most recently at 8 weeks after surgery with a well-healed right hip incision and painless range of motion of his right hip. He continues to rehabilitate from his multiple other injuries because of the polytrauma nature of his injury. His follow-up radiographs do not show any evidence of dislocation or trunnion complications of his right hip.

Discussion

Cold welding, or contact welding, is a solid-state process of joining metals that has been occurring naturally and practiced through engineering for centuries. The process occurs when repetitive or constant pressure forces 2 individual segments of relatively soft metal together, which breaks down the oxide barrier between the segments and joins them by transport of atoms via anatomic diffusion [27]. This is a process seen in aerospace, engineering, and nanotechnology and more recently has been described in arthroplasty. Cold welding of the modular neck and stem interface is documented in the literature as a known complication of modular THA [20-24]. Fraitzl et al recently studied the removal of Sivash-range of motion (S-ROM, DePuy Synthes, Warsaw, IN) THAs and found that 27% of the retrieved devices could not be dissociated intraoperatively [20]. Another recent article stated that cold-welded components may actually be protective from fretting and

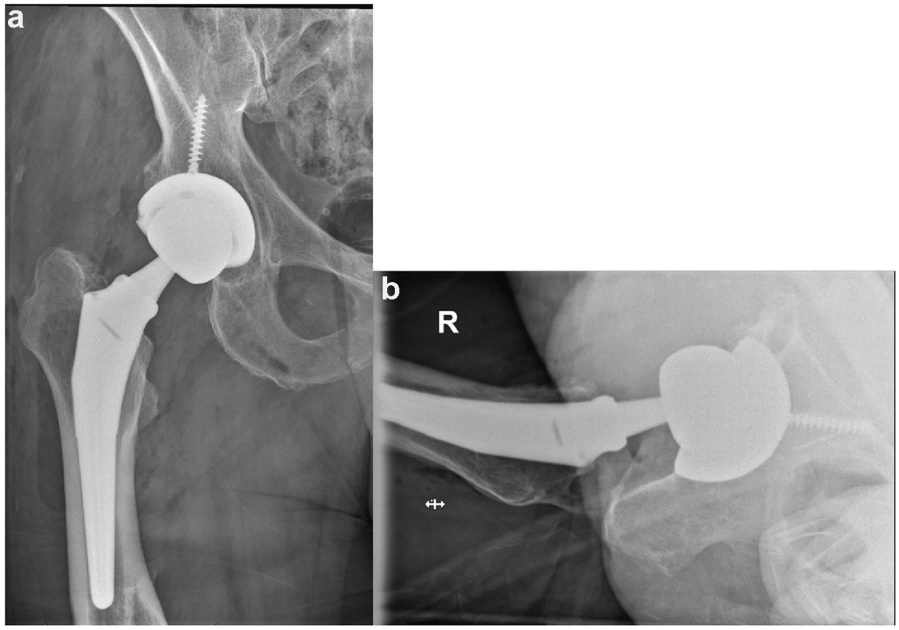

Figure 5. Postoperative anteroposterior radiograph (a) and lateral radiograph (b) of the right hip.

corrosion seen with titanium trunnions. They did acknowledge, however, the difficulty this presents when revising these implants [21]. They found that they were unable to dissemble 22% of the titanium-titanium S-ROM modular hips intraoperatively. Cold-welding is seen most commonly in titanium-titanium stem taper junctions, with nearly 25% of revisions of these stem and taper combinations being cold welded in one study [24].

Multiple factors have been hypothesized to contribute to cold welding. Cold welding is commonly seen at the head-neck junction but can also be seen at the neck-stem junction. Fretting and

Figure 6. Postoperative anteroposterior radiograph (a) and lateral radiograph (b) of the left knee demonstrating revision TKA with a distal femoral replacing hinge.

corrosion occur in the absence of a close-fitting, motionless fit between the modular neck and stem. Micromotion allows the release of metallic debris locally and can create a secure cold weld that often cannot be dissociated in the operating room [20]. Cold welding may also be seen in the setting of infection as the low-pH microenvironment increases the local concentration of protons, which could contribute to corrosion or alter the local charge concentration gradient that may influence atomic diffusion. In addition, moisture present between the taper of the stem and the sleeve of the neck during implantation may also increase the risk of corrosion [20]. No correlation has been found between implantation time and corrosion or fretting damage severity [20,28].

Multiple sources state that the cold-welded interface could not be dissociated in the operating room and required the removal of the modular neck and stem en bloc [20-24]. To date, no literature exists on intraoperative techniques to help dissociate the cold-welded components. Thermal shrinkage of titanium has been described in the prosthodontic literature as it pertains to titanium crown cast molding accuracy and shrinkage. The cast shrinkage percentage by volume ranges from 1.55% to 2% in these studies [29,30]. It is uncertain whether this cast shrinkage causes any long-lasting structural damage or geometric changes of the trunnion, leading to a possible mismatch with engagement of a new modular neck. Future biomechanics studies would be warranted to determine if this method of thermal shrinkage causes permanent microscopic or macroscopic damage to the modular component and whether this could cause any mismatch at either the neck-stem or head-neck junction.

Theoretically, cooling the modular titanium component of this implant with intraoperative ice bath allowed thermal shrinkage of the implant and allowed the titanium of the modular neck and the stem to cryogenically separate. This allowed for dissociation of the neck-stem interface with only moderately applied force. In this case, we were able to retain the well-fixed stem in a multiply injured patient and reduce the morbidity of this revision THA and, equally importantly, refrain from postoperative weight-bearing restrictions, which would certainly hinder recovery. This method of using sterile ice intraoperatively as an option to potentially cryogenically separate cold-welded components appears to be a safe, cost-effective technique and has the potential to avoid a larger and potentially unnecessary operation.

Summary

This case report discusses a novel intraoperative approach to dissociation of a cold-welded modular total hip component. Sterile ice may be used to cryogenically separate the neck-stem interface and prevent the need to remove a well-fixed stem.

Conflict of interest

Jeff Frandsen, MD and Ian Duensing, MD declare they have no competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. Lucas Anderson, MD is a paid consultant for Medacta. He owns stock in OrthoGrid. He receives research support as a primary investigator from Stryker and Zimmer/Biomet. Jeremy Gililland, MD receives royalties from OrthoGrid. He is a paid consultant for OrthoGrid, Stryker, Smith & Nephew, DJO, and ConvaTec. He owns stock in OrthoGrid and Connextions. He receives research support as a primary investigator from Stryker and Zimmer/Biomet. He is on the editorial board for the Journal of Arthroplasty. He is a board member of the American Association of Hip and Knee Surgeons, an education committee member of the American Association of Hip and Knee Surgeons, a program committee member of the American Academy of Orthopaedic Surgeons, and a member of the Orthopaedic Video Theater Committee.

For full disclosure statements refer to https://doi.org/10.1016/j.artd.2020.05.018.

References

[1] Grupp TM, Weik T, Bloemer W, Knaebel HP. Modular titanium alloy neck adapter failures in hip replacement–failure mode analysis and influence of implant material. BMC Musculoskelet Disord 2010;11:3.
[2] Gofton WT, Illical EM, Feibel RJ, Kim PR, Beaule PE. A single-center experience with a titanium modular neck total hip arthroplasty. J Arthroplasty 2017;32(8):2450.
[3] Traina F, De Fine M, Biondi F, Tassinari E, Galvani A, Toni A. The influence of the centre of rotation on implant survival using a modular stem hip prosthesis. Int Orthop 2009;33(6):1513.
[4] Atwood SA, Patten EW, Bozic KJ, Pruitt LA, Ries MD. Corrosion-induced fracture of a double-modular hip prosthesis: a case report. J Bone Joint Surg Am 2010;92(6):1522.
[5] Dangles CJ, Altstetter CJ. Failure of the modular neck in a total hip arthroplasty. J Arthroplasty 2010;25(7):1169.e5.
[6] Ellman MB, Levine BR. Fracture of the modular femoral neck component in total hip arthroplasty. J Arthroplasty 2013;28(1):196.e1.
[7] Skendzel JG, Blaha JD, Urquhart AG. Total hip arthroplasty modular neck failure. J Arthroplasty 2011;26(2):338.e1.
[8] Sotereanos NG, Sauber TJ, Tupis TT. Modular femoral neck fracture after primary total hip arthroplasty. J Arthroplasty 2013;28(1):196.e7.
[9] Wilson DA, Dunbar MJ, Amirault JD, Farhat Z. Early failure of a modular femoral neck total hip arthroplasty component: a case report. J Bone Joint Surg Am 2010;92(6):1514.
[10] Wodecki P, Sabbah D, Kermarrec G, Semaan I. New type of hip arthroplasty failure related to modular femoral components: breakage at the neck-stem junction. Orthop Traumatol Surg Res 2013;99(6):741.
[11] Wright G, Sporer S, Urban R, Jacobs J. Fracture of a modular femoral neck after total hip arthroplasty: a case report. J Bone Joint Surg Am 2010;92(6):1518.
[12] Werner SD, Bono JV, Nandi S, Ward DM, Talmo CT. Adverse tissue reactions in modular exchangeable neck implants: a report of two cases. J Arthroplasty 2013;28(3):543.e3.
[13] Viceconti M, Ruggeri O, Toni A, Giunti A. Design-related fretting wear in modular neck hip prosthesis. J Biomed Mater Res 1996;30(2):181.
[14] Viceconti M, Baleani M, Squarzoni S, Toni A. Fretting wear in a modular neck hip prosthesis. J Biomed Mater Res 1997;35(2):207.
[15] Molloy DO, Munir S, Jack CM, et al. Fretting and corrosion in modular-neck total hip arthroplasty femoral stems. J Bone Joint Surg Am 2014;96(6):488.
[16] Meftah M, Haleem AM, Burn MB, Smith KM, Incavo SJ. Early corrosion-related failure of the rejuvenate modular total hip replacement. J Bone Joint Surg Am 2014;96(6):481.
[17] Kop AM, Swarts E. Corrosion of a hip stem with a modular neck taper junction: a retrieval study of 16 cases. J Arthroplasty 2009;24(7):1019.
[18] Gill IP, Webb J, Sloan K, Beaver RJ. Corrosion at the neck-stem junction as a cause of metal ion release and pseudotumour formation. J Bone Joint Surg Br 2012;94(7):895.
[19] Cooper HJ, Urban RM, Wixson RL, Meneghini RM, Jacobs JJ. Adverse local tissue reaction arising from corrosion at the femoral neck-body junction in a dual-taper stem with a cobalt-chromium modular neck. J Bone Joint Surg Am 2013;95(10):865.
[20] Fraitzl CR, Moya LE, Castellani L, Wright TM, Buly RL. Corrosion at the stem-sleeve interface of a modular titanium alloy femoral component as a reason for impaired disengagement. J Arthroplasty 2011;26(1):113.
[21] Kop AM, Keogh C, Swarts E. Proximal component modularity in THA–at what cost? An implant retrieval study. Clin Orthop Relat Res 2012;470(7):1885.
[22] Pallini F, Cristofolini L, Traina F, Toni A. Modular hip stems: determination of disassembly force of a neck-stem coupling. Artif Organs 2007;31(2):166.
[23] Varini E, Cristofolini L, Viceconti M, Traina F. Stem damage during implantation of modular hip prostheses. Artif Organs 2006;30(7):564.
[24] Whittaker RK, Zaghloul AM, Hothi HS, et al. Clinical cold welding of the modular total hip arthroplasty prosthesis. J Arthroplasty 2017;32(2):610.
[25] Shah R, Talmo C, Nandi S. Titanium neck-titanium stem taper corrosion in a modular neck stem. Arthroplast Today 2019;5(2):145.
[26] Hernandez A, Gargallo-Margarit A, Barro V, Gallardo-Calero I, Sallent A. Fracture of the modular neck in total hip arthroplasty. Case Rep Orthop 2015;2015:591509.
[27] Wagle DV, Baker GA. Cold welding: a phenomenon for spontaneous self-healing and shape genesis at the nanoscale. Mater Horizons 2015;2(2):157.
[28] Cook SD, Barrack RL, Baffes GC, et al. Wear and corrosion of modular interfaces in total hip replacements. Clin Orthop Relat Res 1994:80.
[29] Nishimura F, Watari F, Nakamura H, Fukumoto R, Morita N. [Casting accuracy and shrinkage of titanium castings made with zirconia investments]. Shika Zairyo Kikai 1990;9(6):850.
[30] Ferreira AR, Adabo GL, Filho OP, Soares da Rocha S, Fonseca RG. Evaluation of the thermal shrinkage of titanium and the setting and thermal expansion of phosphate-bonded investments. J Prosthet Dent 2007;98(1):24.