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AAHKS Symposium: Corrosion at the Head-Neck Junction: Why is this Happening Now?

Evaluation of the Painful Dual Taper Modular Neck Stem Total Hip Arthroplasty: Do They All Require Revision?

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ABSTRACT

Although dual taper modular-neck total hip arthroplasty (THA) design with additional neck-stem modularity has the potential to optimize hip biomechanical parameters by facilitating adjustments of leg length, femoral neck version and offset, there is increasing concern regarding this stem design as a result of the growing numbers of adverse local tissue reactions due to fretting and corrosion at the neck-stem taper junction. Implant factors such as taper cone angle, taper surface roughness, taper contact area, modular neck taper metallurgy, and femoral head size play important roles in influencing extent of taper corrosion. There should be a low threshold to conduct a systematic clinical evaluation of patients with dual-taper modular-neck stem THA using systematic risk stratification algorithms as early recognition and diagnosis will ensure prompt and appropriate treatment. Although specialized tests such as metal ion analysis and cross-sectional imaging modalities such as metal artifact reduction sequence magnetic resonance imaging (MARS MRI) are useful in optimizing clinical decision-making, overreliance on any single investigative tool in the clinical decision-making process for revision surgery should be avoided.

Modularity in total hip arthroplasty (THA) allows surgeons to optimize implant reconstruction to patient anatomy intraoperatively [1]. Dual taper modular femoral neck stem THA implants possess interchangeable necks, providing additional modularity at the neck-stem interface [2,3]. Dual modular taper design has the potential to allow precise reconstruction of the center of rotation of the hip by facilitating adjustments of leg length, femoral neck version, and offset to optimize hip biomechanical parameters [4]. Other purported benefits include facilitation of surgical procedures, such as revision arthroplasty [5] and minimally invasive surgical techniques [6], and economic benefit of enhanced implant inventory control [7]. Modularity-related failure modes include modular neck fracture, dissociation of the taper junction, and mismatch of the femoral head and taper connection [8-13]. However, more recently, there is increasing concern regarding this stem design as a result of the growing numbers of clinical failures due to fretting and corrosion at neck-stem taper junction, in a process that has been described as mechanically assisted crevice corrosion (MACC) [14]. These modular junctions are subjected to axial and cantilever-type bending stresses, leading to metal-on-metal (MoM) micromotion. This has been known to generate metal ion debris with subsequent elevation of serum cobalt (Co) and chromium (Cr) ion levels and taper corrosion related adverse local tissue reactions [14,15]. In 2012, a manufacturer initiated a voluntary product recall of modular femoral neck stems. At that point of time, it was estimated that >30,000 patients received the recalled modular neck stem implants worldwide [16]. Therefore, the focus of this article is to review up-to-date evidence in optimizing evaluation and diagnosis of adverse local tissue reactions in patients with contemporary dual taper modular-neck THA and to identify the areas for future research to provide a useful resource for orthopedic surgeons.

Factors Associated With Modular Neck Taper Corrosion

Implant, surgical, and patient factors have been identified as likely contributing factors responsible for taper corrosion in dual modular neck stem THA.

Implant Factors

Implant factors that include taper cone angle, taper surface roughness, taper contact area, modular neck taper metallurgy,

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flexural rigidity of the stem, and femoral head size play important roles in influencing extent of taper corrosion. Narrow cone angled tapers have greater potential for micromotion and may explain higher fretting scores reported at the taper base of 11/13 taper designs compared with 12/14 and 14/16 tapers [17]. Rough-surface tapers were initially developed for use in ceramic heads, and surface roughness has been linked to increased fretting in modular MoM head-neck taper junctions [18]. In vivo corrosion (MACC) are more commonly seen in dissimilar alloy pairings (eg, titanium [Ti] alloy stem and CoCr head) [19]. Conversely, ceramic femoral heads have been reported to decrease taper tribocorrosion [20]. Taper geometric parameters such as length, taper contact area, and resultant lever arm contribute to taper corrosion. Femoral stems with longer modular neck lengths had significantly higher corrosion scores [21]. This corresponds with higher fretting scores noted with increased taper contact area [22]. However, there have been reports that describe increased edge loading at the base of short taper trunnions [23]. In addition, "long varus" necks demonstrate 32.7% greater bending moments when compared with "short varus" necks [11] which potentiates cantilever bending in vivo and resultant micromotion, fretting, and corrosion [21]. In relation to this, beta titanium alloy (Ti12Mo6Zr2Fe) with decreased flexural stiffness has been associated with increased fretting and corrosion [24]. These effects may be aggravated with the use of larger head sizes (>32 mm), which increase torsional forces at the taper trunnion [25]. Larger head sizes may increase offset and varus neck shaft angle, leading to increased lever arm [23], and have been recognized as a contributing factor in the increased failure rates of head-neck modular taper corrosion in MoM THA [26].

Surgical Assembly

Intraoperative surgical assembly may play an important role. In vitro studies have demonstrated greatly reduced (>50%) load to failure with a contaminated assembly compared with a well-cleaned assembly [27] and has been shown to affect cantilever micromotion of dual modular taper neck stems [28].

Patient Factors

Potential patient factors associated with modular neck taper corrosion–related adverse local tissue reaction (ALTR) include metal hypersensitivity, body mass index (BMI), and activity level. Implant-related metal hypersensitivity has been reported since 1990s [29]. Although ALTR has been associated with taper corrosion secondary to MACC, ALTR has also been observed in the absence of high wear or metallosis [30-32]. Histologic examination of periprosthetic tissues in dual-taper THA patients undergoing revision surgery has demonstrated features suggestive of metal hypersensitivity [33,34]. Although increased BMI and increased activity levels would potentially increase the stresses borne by the modular trunnions, however, to date, no correlations have been reported between ALTR in dual modular stem neck THA and BMI or increased activity levels [31,35].

Systematic Evaluation

A painful modular dual taper stem neck THA can present with a myriad of symptoms and may be attributable to various intrinsic and extrinsic causes. A systematic evaluation should include focused clinical history, detailed physical examination, laboratory tests, and cross-sectional imaging to identify potential differential diagnoses in a patient with painful dual modular taper THA [36,37]. A consensus systematic risk stratification algorithm from the American Association of Hip and Knee Surgeons (AAHKS), the American Academy of Orthopaedic Surgeons (AAOS), and the Hip Society has been recently published to guide physicians based on currently available evidence [38] to initiate prompt and appropriate treatment.

Clinical Evaluation

The clinician should obtain a complete history when evaluating patients with a dual modular femoral neck stem THA. The characteristics, site, severity, duration, and onset of the pain provide important information [37,38]. Joint sepsis must be suspected in patients with a history of delayed wound healing, or hip pain after recent gastrointestinal or dental procedures. The clinician should also enquire about any discomfort caused by fullness or swelling around the hip. Physical examination should begin with inspection of the skin for signs of infection and previous scars. Palpation around the hip may reveal the presence of soft tissue masses. Range of motion of the affected hip should be tested as reproduction of pain on passive extension and active flexion may indicate iliopsoas tendinopathy. Strength of hip abduction should also be examined. A comprehensive spine and neurovascular examination is essential to exclude potential confounding neurogenic and vascular causes of pain [37].

Implant Modularity

It is important to recognize that different types of material options exist at the neck-stem junction of a dual-taper modular femoral THA. Different combinations of neck and stem materials may be used at the neck-stem modular junction of dual-taper stem THAs and include the following:

1. Ti modular neck on Ti stem (Ti/Ti).
2. CoCr modular neck on titanium stem (CoCr/Ti).
3. CoCr modular neck on CoCr stem (CoCr/CoCr).

To date, most taper-corrosion–related adverse tissue reactions have been reported in dual taper modular femoral THAs with CoCr modular neck on titanium stem (CoCr/Ti) modular junctions.

Inflammatory Markers (ESR/CRP) and Hip Joint Aspiration

Serum inflammatory markers (erythrocyte sedimentation rate [ESR]/C-reactive protein [CRP]) are frequently elevated in a setting of taper corrosion and, this can occur in isolation, or may suggest presence of concurrent or isolated periprosthetic infection (PJI) [39,40]. Taper corrosion may also mimic the diagnosis of PJI, and this warrants hip aspiration for culture and differential counts [41]. However, synovial fluid counts are also affected by the presence of metallic debris which requires manual counting to reduce errors from metallic debris contamination [42]. Although ESR and CRP have limited value in the diagnosis of PJI in dual-taper modular implants with corrosion, these inflammatory markers may be useful in excluding PJI. In addition, there should be a low threshold to perform synovial fluid hip aspiration in the setting of elevated inflammatory markers. Newer methods to determine the presence of infection such as leukocyte esterase strip tests, alpha defensin, and polymerase chain reaction methods are potentially useful to detect PJI in the presence of taper corrosion in dual modular neck stem THA patients [43].

Metal Ion Levels

Co and Cr ion levels are influenced by the implant type, metallurgy, design of neck-stem taper interface, head size, and