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Complications - Other

Metal Ion Levels Are Not Correlated With Histopathology of Adverse Local Tissue Reactions in Taper Corrosion of Total Hip Arthroplasty

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ABSTRACT

Background: The underlying biological mechanism in the formation of adverse local tissue reaction in taper corrosion of total hip arthroplasty (THA) remains unknown. This study evaluated whether there was a dose-dependent relationship between metal ion levels, intraoperative tissue damage and ALVAL (aseptic lymphocyte-dominated vasculitis-associated lesion) scores in dual taper THA patients who underwent revisions for taper corrosion.
Methods: We performed a retrospective review of 31 dual taper THA patients who underwent revision surgery from May 2013 to October 2013. Preoperative serum metal ion levels, intraoperative tissue damage grading, and ALVAL scores were reviewed. Multivariate analysis was performed to determine if an association existed between metal ion levels, intraoperative tissue damage, and ALVAL scores.
Results: Findings consistent with adverse local tissue reaction were found in all cases. We noted 10 patients with low, 8 with moderate, and 13 with high ALVAL scores, respectively. For intraoperative tissue damage, we recorded 2 (grade 1), 22 (grade 2) and 7 (grade 3) cases. Preoperatively, there was preferential elevation of serum cobalt (3.8 ng/mL, 2.3-17.0) compared to serum chromium (1.0 ng/mL, 0.2-5.8). There was no correlation between preoperative metal ion levels and intraoperative tissue damage ($R = -0.06$, $P = .74$) or ALVAL scores ($R = -0.04$, $P = .481$). There was also no correlation between intraoperative tissue damage and ALVAL score ($R = -0.06$, $P = .73$).
Conclusion: There was no significant correlation between ALVAL scores and prerevision surgery metal ion levels or intraoperative tissue damage, suggesting that the biological mechanism of histologic morphology cannot be solely attributed to elevated metal ion levels and is likely multifactorial, reflecting a complex interplay between implant and patient factors.

Modularity has played an important role in the design of modern total hip arthroplasty (THA) implants. Initial success with femoral head-neck modularity led to the development of modular dual taper necks to provide additional reconstructive options to aid surgeons in the restoration of normal hip anatomy [1]. Modular dual taper neck stems in THA have interchangeable modular necks, facilitating limb length, femoral offset, and version correction, with the potential of enhancing stability and optimizing hip biomechanical parameters by accurately reproducing the center of rotation of the hip [2, 3]. However, it has been long recognized that modularity will increase the potential for corrosion at the modular junction. [4]

To date, increasing number of studies have reported corrosion-related adverse local tissue reactions (ALTRs) or aseptic lymphocyte-dominated vasculitis-associated lesions (ALVALs)

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occurring in modular dual taper THA, which were initially described as a complications of metal-on-metal (MoM) bearings [5-12]. The characteristics of adverse soft tissue reactions detected on metal artifact reduction sequence magnetic resonance imaging (MRI) appear to be similar to those observed in patients with MoM THAs, which include periprosthetic cystic and/or solid lesions and tendon avulsions [6,9]. Furthermore, elevated metal ion levels have also been reported in modular neck THA failures presenting with ALTR [10]. Although ALTR has been linked to modular junction mechanically assisted crevice corrosion and elevated metal ion levels, ALTR has also been observed in the absence of high wear or metallosis [13-15].

The underlying biological mechanism leading to the formation of ALTR in patients with taper corrosion of THA remains largely unknown. Few studies have examined the histologic features in periprosthetic tissues of patients with modular dual taper THA undergoing revision. These studies have demonstrated histologic features that indicate metallic wear and metal hypersensitivity [16, 17]. In addition, several studies have described strong correlations between metal ion levels in serum and positive correlation of elevated metal ion levels and patients with periprosthetic ALTR [18-20]. To our knowledge, however, the potential dose-dependent relationship between metal ion levels, histologic grades (ALVAL scores), and intraoperative tissue damage in taper corrosion-related ALTR reactions has not been previously evaluated. Therefore, the objective of this study was to (1) characterize metal ion levels, intraoperative tissue, histologic features, and immunologic response of ALTRs and (2) determine if there was a correlation between metal ion levels, intraoperative tissue damage, and ALVAL scores in modular dual taper THA patients who underwent revisions for taper corrosion.

Methods

Study Design and Patient Demographics

After receiving approval from our institutional review board, we retrospectively reviewed 31 hips in 31 THA patients with dual taper femoral stems who underwent revision hip arthroplasty from May 2013 to October 2013. Indications for revision THA included elevated cobalt and chromium serum metal ion levels in symptomatic patients with dual taper modular neck stems in THA with the presence of adverse tissue reaction on cross-sectional imaging. At the time of revision, there were 17 women and 14 men with a mean age of 57.4 ± 10.5 years and a mean body mass index of 29.1 ± 5.3. These patients described their pain as being diffuse around the hip region or localized to the groin or thigh.

Indications for index primary THA included osteoarthritis (79%), avascular necrosis (9%), femoral neck fracture (3%), hip dysplasia (3%), psoriatic arthritis (3%), and Stickler syndrome (3%). The type of the femoral component, femoral stem size, head size, femoral offset, and bearing surfaces were recorded (Table 1). The bearing surfaces were primarily ceramic on highly crosslinked polyethylene (74%) with the remainder being cobalt chromium on highly crosslinked polyethylene articulations (26%). Femoral stems included the ABG II Modular stem (Stryker Orthopaedics, Mahwah, NJ; 74%) with gas atomized dispersion strengthened cobalt chromium alloy modular necks and Rejuvenate Total Hip System stems (Stryker Orthopaedics) with wrought cobalt chromium alloy modular necks (26%; Stryker Orthopaedics).

Prerevision Surgery Evaluation

Serum metal ion levels, plain radiographs, and MRI with metal artifact reduction sequence protocol were performed in all patients at the time of initial presentation. Preoperative erythrocyte sedimentation rate (ESR), C-reactive protein (CRP), and white blood cell (WBC) count were collected. There were no infection cases identified based on definition of the musculoskeletal infection society [21]. Primary total hips were revised at a mean of 27.5 ± 9.5 months (Table 1). The revision surgery was performed using "top-out" technique for the femoral stem removal without extended trochanteric osteotomy using high-speed burrs through a posterior approach [22]. Intraoperative tissue damage was determined and graded intraoperatively by the operating surgeon in accordance with a previously published grading system as follows: grade 0 = normal tissue; grade 1 = fluid collection ± mild synovial reaction ± pseudocapsular dehiscence; grade 2 = grade 1 + moderate-to-severe synovial reaction ± metallosis; or grade 3 = grade 2 + abductor damage and/or bone loss [23].

Table 1
Demographic Summary.

Parameter	Revision Cases (n = 31)	
Age in years ± SD	57.4 ± 10.5	
Body mass index in kg/m^2 ± SD	29.1 ± 5.3	
Gender (%)	14 Males (45%), 17 females (55%)	
Preoperative blood investigations (normal range)		
WBC (4.5-11.0 WBC/μL)	6.07 ± 1.39	
CRP (<8 mg/L)	9.13 ± 4.03	
ESR (0-13 mm/h)	24.7 ± 14.1	
Time to revision (mo)	27.5 ± 9.5	
Parameter	**Stryker ABG II (n = 23)**	**Stryker Rejuvenate SPT (n = 8)**
Preoperative implant data		
Stem size	4.2 ± 1.2	8.5 ± 1.7
Head size (mm)	31.2 ± 3.7	38.5 ± 4.8
Offset (°)	−1.2 ± 1.7	0.7 ± 2.2
Bearing type	CoP 19 MoP 4	CoP 5 MoP 3
Time to revision (mo)	26.8 ± 8.8	29.4 ± 11.8
CoP	27.4 ± 7.1	29.6 ± 12.9
MoP	25.5 ± 11.0	29.0 ± 7.0

SD, standard deviation; WBC, white blood cell; CRP, C-reactive protein; ESR, erythrocyte sedimentation rate; CoP, ceramic on highly crosslinked polyethylene; MoP, cobalt chromium on highly crosslinked polyethylene.

Histologic Analysis and Flow Cytometry

In all cases, soft tissue surrounding the implant was taken intraoperatively and fixed in 10% formalin immediately after removal. Multiple sections were obtained from 10 different sites in each retreived sample and embedded in paraffin blocks for routine staining with hematoxylin and eosin. Hematoxylin and eosin stained tissue sections were examined and evaluated by 2 observers, who reviewed up to 45 slides per case. The tissue sections were evaluated for the quality of synovial lining, type of inflammatory infiltrate, and tissue organization based on the ALVAL scoring system [24]. The ALVAL scoring system is a 10-point histologic score used to semi-quantify the degree of ALVAL by examination of synovial lining integrity, inflammatory cell infiltrates, and tissue organization. Based on this system, a score of <4 is considered low, between 5 and 8 moderate, and >9 high. As there were considerable morphological variations across tissue sections from the same case, the highest observed score in each case was used as its ALVAL score. The tissue sections were also examined for the presence of wear debris and for any other significant histologic findings.

Flow cytometry of the samples were performed to assess the immune response. Hip capsule lymphocytes were obtained by