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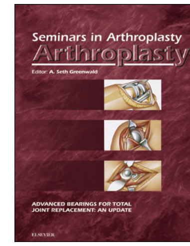

Femoral neck modularity: A bridge too far

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ABSTRACT

Modular femoral neck use in total hip arthroplasty (THA) affords the operating surgeon increased intra-operative flexibility with regard to offset, version, and leg length. Proponents also advocate a reduced dislocation rate, reduced impingement issues, and ease of revision of acetabular component, head, or neck. However, the increased intra-operative flexibility and potential postoperative advantages come at a significant price. Adverse events and complications associated with modular femoral neck usage are being reported with increasing frequency. Modular femoral neck fractures as a result of patient- and implant-related factors are prevalent. Corrosion at the neck–stem interface is associated with a number of sequelae, including osteolysis, synovitis, adverse local tissue reactions (ALTRs), and aseptic lymphocyte-laminated vascular-associated lesions (ALVAL). Systemic complications of metallosis are also pertinent following corrosion at the neck–stem junction. Failure to disassemble the neck from the stem due to corrosion and cold welding is a documented complication and obviates a potential benefit of modularity at the time of revision. Modular femoral necks have a twofold increase in overall revision rate in the Australian registry data as compared to fixed-neck stems. Lastly, modular femoral necks add significant cost to each THA. The purpose of this review article is to discuss the current state of femoral neck modularity and provide the readership with pause prior to the continued use of modular femoral neck THA. Given the current and emerging literature, the modular femoral neck is a bridge too far.

1. Introduction

The increased use of modularity in total hip arthroplasty (THA) occurred in the late 1980s and early 1990s due to a series of studies describing the variability in leg length, version, and offset of the lower extremity and hip [1,2]. The described intra-operative advantages of modularity are the ability to independently adjust the aforementioned variables of leg length, offset, and version [3–7]. The theoretical postoperative advantages owing to intra-operative flexibility include decreased dislocation rates and decreased mechanical impingement [3–7]. In addition, authors have advocated that in an era of minimally invasive THA, neck modularity affords the surgeon the ability to "build" the implants in situ through smaller incisions [8]. Proponents of the modular neck also discuss the ease of revision in cases of acetabular component, liner or head revision in the face of a well-fixed stem. Lastly, authors have noted the potential for decreased component inventory given the increased intra-operative flexibility [3].

Interestingly, it was not long after the first description of modularity that concerns began to arise [4,9–13]. Early designs of the modular taper lent themselves to fretting and crevice corrosion. Modifications to implant materials initially quelled concerns regarding the degradation process. These design modifications led to a period of relative neutrality regarding usage of

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the modular neck in THA [14]. However, clinical failures began to mount in the literature: unintentional dissociation of neck from stem, failures to disassemble neck from stem during revision surgery, modular neck fractures, corrosion, and the sequelae thereof [8,15–26]. These results led to renewed interest in the mechanisms of these clinical failures, the results of which are outlined below.

2. Modular femoral neck fracture

The adverse clinical outcome of modular neck fracture is relatively rare; however, the frequency of case reports has increased [15,16,18,21,22,27]. One large case series exists in which 5000 titanium (Ti) modular neck THAs were evaluated and an incidence of adverse outcomes of 1.4% was reported [19]. Since then a multitude of case reports and case series has entered the literature [20,21,23,26,27]. Several patient, surgeon, and implant factors have been hypothesized to contribute to adverse outcomes. Contributing patient factors may include male gender and patient weight greater than 100 kg [15,19,21,22]. Surgeon factors are related to the technique of implantation, taking care to impact the neck into the stem as accurately as possible and ensuring that all debris (bone chips) and liquid (blood and irrigant) are removed from the stem prior to impacting the neck [19,28]. Jauch et al. [28], in a controlled biomechanical experiment, demonstrated that debris-contaminated modular necks had increased micromotion compared to clean interfaces and that Ti components had significantly higher micromotion than cobalt–chromium (CoCr) components under comparable conditions. They postulated that increased micromotion leads to fretting and fatigue failures [28]. The implant-related factors appear to be numerous [15,19,22,24]. All other factors being equal, Ti neck implants have been postulated to fail due to fracture more frequently than CoCr necks, given the lower modulus of elasticity for titanium [29]. The use of "long varus" necks and implants with neck-shaft angles greater than 135° may increase the bending moment causing mechanical stress on the neck–stem junction. This increase in mechanical stress has been implicated as a cause of micromotion, corrosion, and neck fracture [15,19,22,24,30]. Skendzel et al. [15] reported on two cases of "long varus" modular neck fractures and cited a 32.7% increase in the bending moment as compared to the standard "short varus" neck.

Although a much less frequent occurrence, fracture of a metaphyseal–diaphyseal modular femoral system may also occur. In a retrospective review of this type of implant, Lakstein et al. [31] reported on three implants with six mid-stem fractures. After a microscopic evaluation of the components, the authors postulated that fretting fatigue had caused the fractures and that increased patient weight and a lack of proximal bone stock were associated risk factors for fracture [31]. The importance of adequate bone stock was further emphasized in the presence of modular junctions by Chu and colleagues [32] through the use of a finite element model of the modular interface in the presence and absence of stable osseous support. Their results suggest that in the absence of adequate bone stock, the peak stress across modular interface was increased 45% [32].

3. Modular femoral neck corrosion

Corrosion has been examined at both the femoral head–neck junction and the femoral neck–stem junction [3,4,10,12,19,33–35]. Both CoCr and Ti implants form a biocompatible passivation layer that confers some degree of corrosion resistance in its intact state [28,36]. The process of corrosion typically begins with micromotion at the neck–stem interface due to the higher loads experienced at this junction as compared to the neck–head junction [19,24,28,35,37]. Micromotion leads to the mechanical removal of the passivation layer on the surface of the components and creates a local environment ripe for the propagation of corrosion [38]. Both CoCr and Ti implants are then susceptible to fretting and crevice corrosion. In the case of Ti implants, the loss of the passivation layer allows for not only crevice corrosion but also hydrogen embrittlement, a process that significantly weakens the material [9,38]. The end results for both CoCr and Ti implants are an increased propensity to fatigue failure and fracture as discussed previously. Furthermore, the corrosion process is not without its effects on the biologic environment as well. The end-products of the corrosion lead to an increase in metal debris that may act locally within the bone and soft tissues as well as systemically at the end organs [9].

There are currently conflicting reports on the degree of corrosion, given the material coupling. Research of the head–neck junction has demonstrated that corrosion and fretting have been documented in mixed metal systems (CoCr neck with Ti stem) and in the presence of similar material couplings [24,26,33,35,38–40]. Some groups have advocated the use of CoCr rather than Ti due to lower micromotion and increased fatigue strength [19,28], whereas other studies have found contradictory results [41]. Kop et al. [41] examined 57 modular necks and found that 62% of the CoCr components and 30% of the Ti components exhibited signs of corrosion. Ninety percent of the CoCr and 50% of the Ti components exhibited signs of fretting [41]. The severity of corrosion and fretting was greater at the neck–stem interface as compared to the head–neck interface [41]. Ultimately, there is no definitive answer as to which metal combination is safest or whether there are significant advantages to using two dissimilar metals at an interface. Both CoCr and Ti modular necks have a high propensity for fretting and crevice corrosion and the treating surgeon must be prepared to share these results with those treated with a modular THA. Furthermore, the treating surgeon must warn patients that corrosion positively correlates with duration of implant retention [33,34].

4. Failure to disassemble

An additional complication of Ti–Ti modular neck–stem interfaces is the failure to disassemble the neck from the stem at the time of revision. Fraitzl et al. [26] performed a retrieval study of 22 Ti modular neck devices and found that seven (32%) necks would not disengage from the stems. Kop et al. [41] found that of the 57 retrieved modular devices, failure to disassemble was noted in 22% of the Ti devices.