Arthroplasty Today xxx (2016) 1–6

Contents lists available at ScienceDirect

Arthroplasty Today

journal homepage: http://www.arthroplastytoday.org/

Original research

The stability of dual-taper modular hip implants: a biomechanical analysis examining the effect of impact location on component stability

Nicholas B. Frisch, MD, Jonathan R. Lynch, MD *, Richard F. Banglmaier, PhD, Craig D. Silverton, DO

Department of Orthopaedic Surgery, Henry Ford Health System, Detroit, MI, USA

A R T I C L E I N F O

Article history:
Received 31 May 2016
Received in revised form
14 August 2016
Accepted 17 August 2016
Available online xxx

Keywords:
Total hip arthroplasty
Modularity
Corrosion
Stability

A B S T R A C T

Background: The purpose of this study was to investigate the stability of dual-taper modular implants following impaction forces delivered at varying locations as measured by the distraction forces required to disassemble the components.

Methods: Distraction of the head-neck and neck-stem (NS) tapers of dual-taper modular implants with 0°, 8°, and 15° neck angles were measured utilizing a custom-made distraction fixture attached to a servohydraulic materials test machine. Distraction was measured after hand pressing the components as well as following a simulated firm hammer blow impaction. Impacts to the 0°, 8°, 15° necks were directed axially in line with the neck, 10° anterior, and 10° proximal to the axis of the neck, respectively.

Results: Impaction increased the range of NS component distraction forces when compared to hand pressed components (1125-1743 N vs 248-302 N, respectively). Off-axis impacts resulted in significantly reduced mean (±95% confidence interval) distraction forces (8° neck, 1125 ± 117 N; 15° neck, 1212 ± 73 N), which were up to 35% lower than the mean distraction force for axial impacts to the 0° neck (1743 ± 138 N).

Conclusions: Direction of impaction influences stability of the modular interface. The greatest stability was achieved with impaction directed in line with the longitudinal axis of the taper junction. Off-axis impaction of the 8° and 15° neck led to significantly reduced stability at the NS. Improving stability of dual-taper modular hip prostheses with appropriately directed impaction may help to minimize micromotion, component settling, fretting corrosion, and subsequent failure.

Introduction

Modularity in total hip arthroplasty has offered many benefits including the versatility to fine tune offset, leg length, and version, while also reducing the necessary inventory and cost of the arthroplasty [1-3]. However, each additional modular interface introduces a source for wear particle generation with particulate quantities possibly exceeding that generated at the articular articulate surface [4-6]. While several theories exist as to etiologies of wear-particle generation and subsequent corrosion at the modular interface, research suggests that the process begins with mechanical fretting and disruption of the protective oxide layer leading to the release of metal ions at the taper interface [7,8]. Both the debris and corrosion at the modular surface can have a multitude of effects on the outcome of the prosthesis including osteolysis, adverse local tissue reactions, increased risk of neck failure or fracture, and increased distraction force requirements at revision surgery [9]. It has been postulated that the process of fretting may begin at impaction of the components at index surgery [4], thus indicating the importance of proper engagement and stability of the components to prevent micromotion and subsequent fretting corrosion.

One or more of the authors of this paper have disclosed potential or pertinent conflicts of interest, which may include receipt of payment, either direct or indirect, institutional support, or association with an entity in the biomedical field which may be perceived to have potential conflict of interest with this work. For full disclosure statements refer to http://dx.doi.org/10.1016/j.artd.2016.08.005.

* Corresponding author. 3107 Ferris Ave., Royal Oak, MI 48073, USA. Tel.: +1 260 750 2494.

E-mail address: Jlynch6@hfhs.org

http://dx.doi.org/10.1016/j.artd.2016.08.005

Proper seating of components may help reduce micromotion between the 2 components and increase the load required to initiate fretting [8]. For impacts applied in line with the head and neck taper junctions of the 0° neck, previous research has shown that the stability of the modular taper is determined by the force of impaction, which is directly proportional to the force required to distract the components in this ideal scenario [3]. However, the ability to direct an ideal impaction along the axis of the mating components is exacerbated by implant neck angulation. Prior work in our laboratory has shown significant changes in the impact forces transmitted to the taper junctions for various impact locations and neck angles [10]. Under similar impact conditions (same mass and drop height), the resultant impact force and force measured at the head neck (HN) or neck stem (NS) were affected by the configuration of impact location and neck angle.

In the context of assembling modular hip implants, prior studies have not accounted for the effects of impact location and neck angle on the stability at the modular interface [3,11]. The purpose of the present study was to investigate the effect that impact location has on subsequent stability of both the head-neck (HN) and neck-stem (NS) taper junctions. A secondary objective was to evaluate hand-assembled taper junction stability because weight-bearing taper engagement, subsequent to unimpacted hand assembly of the implant, is an optional surgical procedure.

Material and methods

Modular implants (Wright Medical Technologies, Inc., Arlington, TN) consisted of the stem, neck, and head. Size 9, 139-mm medial length stems, and 32-mm heads were used with long necks having the following 3 orientations: 0° (straight), 8° anterior (A/R), and 15° anterior. Three implants were constructed utilizing each of the 3 different neck angulations, for a total of 9 implants. Each implant was hand assembled then distracted, reassembled by hand, and distracted a second time to obtain the stability measurements ($n = 6$) for nonimpacted implants. Next, each implant was hand assembled, underwent a predefined impact based on the neck angle (described in the following section). Implants were then distracted, reassembled, and impacted again and distracted a second time to obtain the stability measurements ($n = 6$).

Modular hip impact and distraction experiments were conducted to determine the effect that impact location and neck angle has on taper junction stability. Impact configurations were chosen based on previous research, which showed the impact force delivered to a 0° neck was greater than an off-axis impacted 8° neck but less than an off-axis impacted 15° neck [10]. Thus, a low to high range of impact forces were expected to provide a range of implant stabilities. Distraction experiments were conducted on both hand-assembled and impacted implants. Distraction of hand-assembled implants was performed first to establish a baseline stability. HN and NS taper junctions were both distracted to determine the stability of each.

Hand assembly consisted of inserting the neck into the stem, applying firm pressure to engage the NS taper, then seating the head on the neck, and again applying firm pressure to engage the HN taper. For the impacts, each implant was hand assembled, as mentioned previously, then loaded into a custom-built fixture secured in an impact drop tower (Fig. 1). A drop mass impactor was used to simulate a surgeon's firm mallet blow, estimated at 4000 N [11]. That impact load was calibrated to a height of 203 mm above the implant contact point of the axially aligned 0° neck, a height that was consistent across the 8° and 15° neck impacts. For all impact tests, the impactor was raised to the calibrated height, held suspended by a magnetic clamp (MagJig 60, MagSwitch Technology, Inc., Lafayette, CO), then released. The impactor body was a steel mass (700 g), which allowed attachment of a load cell (Model 1051V6, Dytran Instruments, Inc., Chatsworth, CA) to record the impact forces. A Duralon load cell housing covered the load cell, preventing sensor ringing from metal-to-metal impacts. The implants were positioned such that the 0° neck received an axial impact, the 8° neck received a 10° anteriorly off-axis impact (ie, the impact point of contact was anterior to the neck axis), and the 15° neck received a 10° proximally off-axis impact (ie, the impact point of contact was proximal to the neck axis; Fig. 2). Implant positions were adjusted to the desired impact location, clamped in place in the base fixture, and adjusted in the x-y direction to center the head under the impactor.

After hand pressing or impacting the implant, it was loaded into a custom-built distraction fixture to first distract the NS taper junction and then the HN taper junction (Fig. 3). The fixtures were connected to a servohydraulic materials test machine (Model 8501, Instron Corp., Norwood, MA) and pulled apart at a displacement rate of 0.1 mm/s. Distraction force was measured by a load cell (Catalog Number 2518-600, Instron Corp) and recorded on a personal computer. Impact and distraction forces were compared to assess taper joint stability with the ideal axially impacted 0° neck.

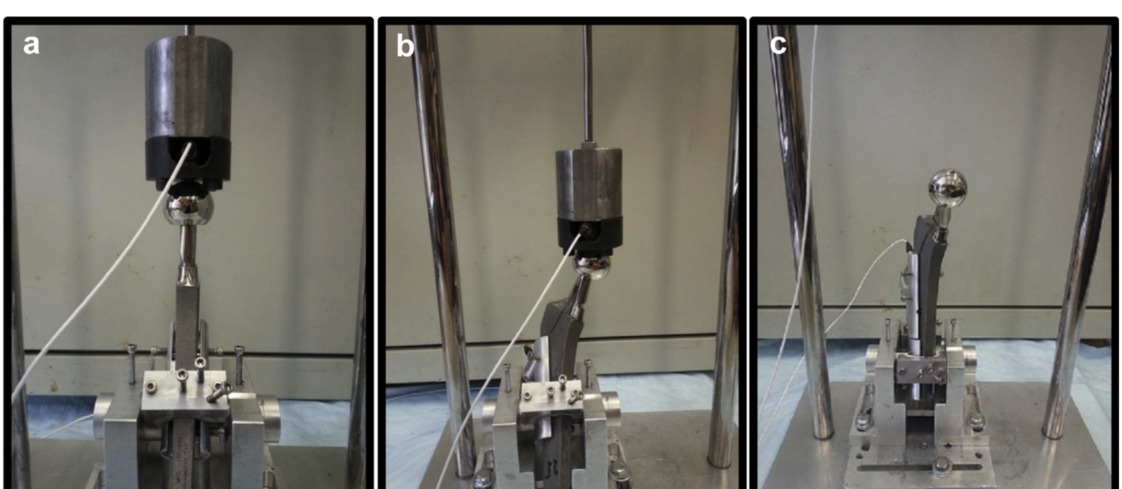

Figure 1. Implants positioned in the drop tower of the impactor. Zero degree neck (a), 8° neck (b), and 15° neck (c).