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A nondestructive method to verify the glenosphere-baseplate assembly in reverse shoulder arthroplasty

Steven Leuridan, MSc[a,*], Quentin Goossens, MSc[b], Leonard Pastrav, PhD[b], Alexander Van Tongel, MD, PhD[c], Lieven De Wilde, MD, PhD[c], Philippe Debeer, MD, PhD[d], Kathleen Denis, PhD[b], Wim Desmet, PhD[e], Jos Vander Sloten, PhD[a]

[a]*Biomechanics Division, Department of Mechanical Engineering, KU Leuven, Leuven, Belgium*
[b]*Health Engineering Technology, Campus Groep T, KU Leuven, Leuven, Belgium*
[c]*Department of Orthopedic Surgery and Traumatology, Ghent University Hospital, Gent, Belgium*
[d]*Department of Orthopedic Surgery, Leuven University Hospitals, Pellenberg, Belgium*
[e]*Production Engineering, Machine Design and Automation Division, Department of Mechanical Engineering, KU Leuven, Leuven, Belgium*

Background: Glenoid dissociation is a rare postoperative complication in reverse shoulder arthroplasty that has severe consequences for the patient and requires revision in most cases. A mechanically compromised Morse taper is hypothesized to be the main cause of this complication, with bony impingements and soft tissue interpositioning being cited as the most important problems. Intraoperative assessment of the taper assembly is challenging. Current methods require applying considerable torque to the glenosphere or relying on radiographs.

Materials and methods: This in vitro study demonstrates how the assembly quality can be accurately determined in a nondestructive way by exploiting the implant-specific relation between screw and Morse taper characteristics by measuring the angular rotation–torque curve.

Results: The feasibility of the method is demonstrated on 2 reverse implant models. Several data features that can statistically discriminate between optimal and suboptimal assemblies are proposed.

Conclusion: Suboptimal assemblies can be detected using the method presented, which could easily be integrated in the current surgical workflow. Clinical recommendations based on the method's rationale are also presented, allowing detection of the most severe defect cases with surgical instruments currently in use.

Level of evidence: Technique Article

Keywords: Reverse shoulder arthroplasty; glenoid dissociation; glenosphere–baseplate assembly verification; Morse taper; smart surgical instruments; nondestructive

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*Reprint requests: Steven Leuridan, MSc, Department of Mechanical Engineering, Biomechanics Division, KU Leuven, Celestijnenlaan 300c, Box 2419, B-3001 Heverlee, Belgium.

E-mail address: steven.leuridan@kuleuven.be (S. Leuridan).

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Reverse shoulder arthroplasty (RSA) has been reported to successfully restore functional outcome in patients with cuff tear arthropathy,[1-3,10,12,13,15,23] rheumatoid arthritis,[21] proximal humeral fractures[1] and tumors,[6] and as a treatment option for revision shoulder arthroplasty.[2,5-7,13] RSA, however, is associated with a relatively high complication rate, with an incidence of more than 20% reported for primary surgery and upward of 40% for revision surgery.[22] Possible complications include acromion, glenoid, or periprosthetic fractures,[1,8,15,25,26] scapular notching, with reported incidences as high as 74%,[2] instability,[1] and glenoid component loosening or dissociation.[1,8] Although dissociation is a rare postoperative complication, with an incidence of 0.72%[4] to 3.2%,[16] revision is necessary in 75% of these cases.[17]

Improper intraoperative engagement of the Morse taper, thereby mechanically compromising the glenosphere–baseplate interface, has been suggested as a possible cause of acute dissociation.[4,11,16] This improper engagement could be caused by an impingement between the underside of the glenosphere and the underlying glenoid due to inadequate reaming (impingement defects)[4,16] or by bone or soft tissue particles that become trapped between the glenosphere and baseplate during assembly (interpositioning defects).[16] Cantilevered engagement of the glenosphere due to impaction under a slight angle, incomplete engagement due to proud or cross-threaded baseplate screws, and humeral interference are additional mechanisms that may lead to a suboptimal glenosphere–baseplate assembly.[4]

Improper engagement of the Morse taper due to impingement may reduce the biomechanical integrity by as much as 60%.[4] Intraoperative verification of whether the Morse taper is properly engaged is challenging, and current methods are not practical intraoperatively due to the high force or torque that needs to be applied to the implant and underlying bone to distinguish a properly from an improperly engaged Morse taper, thus putting the implant at risk.[4]

This study demonstrates a novel, sensitive, nondestructive method that can be easily implemented in the surgical workflow and that allows for the detection of improperly engaged Morse tapers due to impingement or soft tissue interpositioning without the need to apply excessive force or torque to the bone–implant construct. A proof of concept of this method is presented for 2 implant models.

Materials and methods

Method rationale and measurement setup

The method presented in this study is based on processing the angular rotation–torque curve that was measured while engaging the Morse taper by tightening the central locking screw. This measurement was performed using an instrumented screwdriver. For a properly engaged implant, this curve is theoretically determined completely by the design of the Morse taper (taper angle, diameter, and length), the connection length of the glenosphere and baseplate taper surfaces (surface interface length), the design of the glenosphere, and the thread of the central locking screw (diameter, pitch, and lead). These specifications are not standardized in the orthopedic industry,[14] and variations exist in Morse taper and glenosphere design among the implant manufacturers. The baseline curve for a properly engaged assembly was thus expected to be implant specific. Improper engagement of the Morse taper due to impingement or soft tissue interpositioning defects was expected to cause deviations in the angular rotation–torque curve compared with a curve characteristic for a properly engaged Morse taper.

To measure the angular rotation–torque curve, a measurement setup was developed consisting of a Maxon DCX35L electric motor fitted with a Maxon GPX42 gear head providing a 186:1 reduction (Maxon Motor AG, Sachseln, Switzerland), an angular encoder ENX16 EASY with a resolution of 1024 pulses per rotation (Maxon Motor AG), a torque cell HBM T4A (HBM AG, Darmstadt, Germany), and a PCB 352A accelerometer (PCB Piezotronics Inc., Depew, NY, USA) attached to the torque cell housing in the axial direction. Figure 1 depicts the measurement setup. The electric direct current motor was voltage controlled and could apply a maximum torque of 13.5 Nm. Data were collected using the LabVIEW 8.6 system (National Instruments, Austin, TX, USA) at a sampling frequency of 100 Hz.

Two types of glenosphere–baseplate constructs were tested to verify the hypothesis that baseline curves were implant

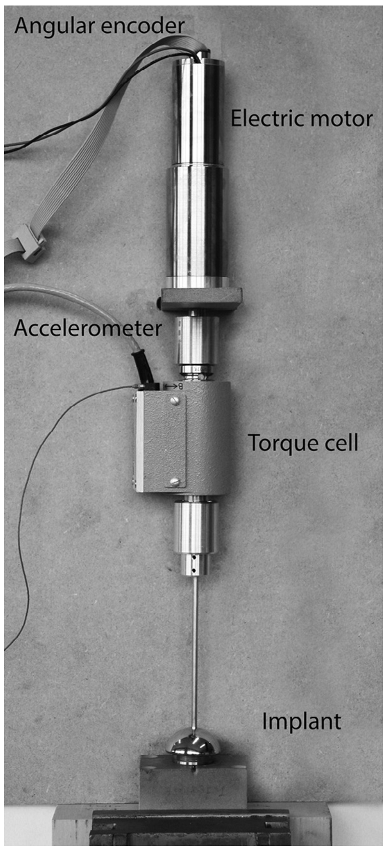

Figure 1 The experimental setup to measure the angular rotation–torque curve while engaging the glenosphere onto the baseplate. Shown is the Delta Xtend implant (DePuy International Ltd., Leeds, United Kingdom).