INTRODUCTION
As total hip arthroplasty (THA) is extended to younger more active patients, the number of revision surgeries is expected to double within 20 years. Since the most common cause of revision is instability or dislocation (41%) a modular neck component could eliminate the need to remove a well-fixed stem. Such systems are being introduced by several manufacturers not only to ease revision surgery but also to allow optimizing hip biomechanics at the time of primary THA. It is imperative to ensure that such systems provide high load bearing capacity and long durability, especially for younger patients. The purpose of this study was to investigate the strength and fatigue performance of a modular neck component. Furthermore, the extraction capacity and long durability, especially for younger patients.

MATERIALS AND METHODS
A commercially-available hip implant (PROFEMUR, Wright Medical Technologies, TN, USA), consisting of a CoCr head and titanium neck and stem components, was tested. The components are assembled with tapered connections. In all in vitro cases a long neck with 8° varus was tested. Tests were carried out according to ASTM standard F2068.

Fatigue testing was performed on manually assembled head, neck and stem in air at 3Hz. Static compression tests were first performed to establish the ultimate load bearing capacity (Fult). Cyclic loading was then carried out at loads of 50%, 75% and 90% of Fult. The number of cycles to failure was recorded to generate a fatigue life curve.

Fatigue-corrosion testing was performed on the modular system in bovine serum at 37°C. Components were assembled with 2.0kN compressive load and cyclic loads of 2.3kN were applied at 10Hz for 0 (assembly load only), 1000, 10000, 100000 and 1 million cycles. A distraction test was then performed parallel to the neck axis to measure the force required to separate the neck and stem. Up to three complete assemblies were tested for each duration. Twelve implants retrieved during revision surgery were provided by the manufacturer, three of which were suitable for a distraction test for comparison with in vitro results. The tapered neck-stem mating surfaces of retrievals and in vitro samples were analyzed using optical (OM) and scanning electron (SEM) microscopes to study potential wear, corrosion and galling damage.

RESULTS
As expected, fatigue life increased with decreasing load level, with failure occurring at 6.5kN after 1 million cycles (Figure 1). Specimens typically failed at the smallest cross section of the neck. The ultimate compressive failure load was found to be 12.6kN to 13.3kN.

No failures occurred during fatigue corrosion testing. Neck pull-off force increased with increasing number of cycles, reaching a maximum of 5.7kN after 100000 cycles (Figure 2). Distraction forces were 3.1, 5.1 and 16 kN for the retrieved implants.

SEM analysis revealed some corrosion and galling damage on the mating surface of the retrieved implants (Figure 3). The strongest corrosion was seen on the implant which also exhibited the highest neck distraction force. The in vitro specimens showed no signs of corrosion. However, all exhibited striation marks on the neck surface corresponding to the entry into the stem taper. In addition, samples tested for 100000 cycles or more showed some fretting damage along the longitudinal edge of the neck mate surface.

DISCUSSION
This study has determined the in vitro fatigue performance of a modular neck system in THA, as well as examined neck pull-off forces, fretting and corrosion of in vitro-tested and retrieved implants.

In vitro pull-off forces increased with increasing cycles to a maximum of 5.7kN after 100000 cycles. The very high distraction force for one of the retrievals (16kN) may be explained by corrosion and possible cold welding of the titanium substrate and would prevent component separation during revision surgery. Excluding this implant, the in vitro and retrieval specimens exhibited similar pull-off forces and patterns of fretting and galling on the tapered surfaces, likely due to initial settling of the tapered junction.

The fatigue corrosion tests were a simplified in vitro simulation of a complex in vivo mechanical and biological environment. Although the in vitro specimens did not show signs of corrosion, fretting patterns and neck pull-off forces agreed well with the retrieved specimens. Only 12 retrieved specimens were available for study, and were implanted by various surgeons and neck geometry was not consistent. The implants were from patients varying in weight and, likely, activity level. Furthermore, the surgeons may have used a variety of assembly techniques which may have affected fluid penetration into the junction or early micromotion of the surfaces.

The modular neck in THA helps surgeons optimize hip biomechanics and facilitates revision surgery in the case of a well-fixed stem. However, as more manufacturers introduce such systems understanding the fatigue performance of a modular neck system, as well as phenomena that occur at the neck-stem junction is critical to evaluating the clinical performance. This study has established the fatigue performance, wear and corrosion characteristics as well as expected distractive forces of an established modular neck system which may be compared with newer systems.

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REFERENCES

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