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Case Report

Laser etching causing fatigue fracture at the neck–shoulder junction of an uncemented femoral stem: A case report

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ABSTRACT

Fatigue fracture of a femoral component in total hip arthroplasty is a rare occurrence but well documented in the literature. It is understood that proximal loosening of a femoral stem with a well fixed stem distally will result in cantilever bending and eventual fatigue fracture of the stem. Other factors which may potentiate a fatigue fracture are material design, implant positioning, and patient characteristics. More recently, laser etching on the femoral neck of an implant has resulted in fatigue fracture. We report a case of a fatigue fracture at the neck–shoulder junction in a well fixed, uncemented, femoral component due to laser etching in the region of high tensile stress.

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Metal fatigue is a common complication of orthopaedic surgery, particularly in the treatment of fractures. It is less commonly seen in arthroplasty surgery; however, with the advent of modular femoral necks and heads, it is being increasingly reported in the literature with rates between 0.23%¹ and 10.7%.² Changes in the manufacture and component design of implants can occur without adequate testing and quality control, which can lead to catastrophic complications and failure. We will discuss the issue of laser etching on the neck of a femoral stem leading to fatigue fracture, and the need for adequate testing of components before being used in the greater population.

In a four-year period, the senior author performed 231 uncemented DePuy Corail stems (DePuy, Warsaw, IN) on 217

patients. There was one (0.43%) registered case of a fatigue fracture of the Corail stem requiring revision surgery.

A 74-year-old man (106.7 kg, 175 cm, BMI: 35 kg/m²), five years and nine months after receiving an uncemented left total hip arthroplasty (THA), presented to the emergency department of a tertiary referral trauma hospital, unable to weight bear on his left leg due to severe pain. The man's leg gave way when he was squatting whilst gardening at home. He was unable to straight leg raise and had a shortened and externally rotated limb. An X-ray (Fig. 1b) of his left hip revealed a prosthetic fracture at the neck–shoulder junction of the femoral stem.

His primary THA was performed in September 2003 with a DePuy Corail femoral stem, which was indicated for severe osteoarthritis of his left hip (Fig. 1a). His post-operative

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Fig. 1 – Radiographs of the total hip arthroplasty before and after the fatigue fracture. a) Post-operative radiograph after primary total hip arthroplasty, b) Follow up radiograph shows fracture at the neck–shoulder junction in a well fixed stem 5 years and 9 months after the primary operation.

recovery was unremarkable. The femoral component used in his primary THA was a size 12 Corail, standard angle, high offset stem with a DePuy Biolox 32, +9 ceramic femoral head. A 54 mm Duraloc 300 cup was inserted with a 54 × 32 mm Duraloc Marathon liner.

The patient underwent a revision of his left femoral stem. Intra-operatively, the femoral stem was well fixed, requiring an extended trochanteric osteotomy for removal. A 13 × 240 mm Stryker Restoration modular stem (Stryker Orthopedics, Mahwah, NJ) with a 21 conical proximal body and a size 32, +8 metal head was inserted. Since the revision THA, this patient has been progressing well with no post-operative complications.

DePuy, Australia, in consultation with the Therapeutic Goods Association,³ Australia, agreed to release a Hazard Alert for the Corail Hip System in February 2004 for Corail femoral stems with laser etching located on the prosthetic neck.

DePuy released a list of product codes of the affected Corail stems. The implant that sustained a fatigue fracture carried the product code, 3L93712 KLA 12, which is listed on the affected product list.

High-resolution digital photographs were taken from an SLR camera of the fractured prosthesis (Fig. 2 and 3). In Fig. 3,

there are signs of beach marks. Beach marks are macroscopically visible semielliptical lines running perpendicularly to the direction of fatigue fracture propagation.

By the time the prosthesis was explanted, majority of the beach marks were gone due to the fractured surfaces burnishing off each end, however there were still some evidence of the beach marks in the inferior portion of the neck, the last portion of the stem to fatigue. The beach marks coupled with the overload zone regions (Fig. 3a) confirm the superior to inferior direction of fatigue crack propagation (Fig. 3b).

A 3D model for the stem was generated by removing the hydroxyapatite (HA) from the Corail stem and laser scanning surfaces to investigate areas of tensile stress. The laser scan data was imported into the finite element analysis software, ANSYS (ANSYS Inc., Canonsburg, PA).

The stem was assigned the following material properties, Young's Modulus = 110 GPa, Poisson's ratio = 0.3. The media used to embed the stem (simulating bone) was assigned the following properties; Young's Modulus = 3 GPa, Poisson's ratio = 0.3. The stem was assumed to be rigidly bonded to the embedding media; similarly, no friction was simulated between the femoral head and the taper on the stem. The analysis

Fig. 2 – Photograph of the fractured Corail stem prosthesis, a) Fatigue fracture through laser etching on the femoral neck, b) Beach marks on closer view of the fatigue fracture.

Fig. 3 – Photograph of the fractured Corail stem prosthesis, a) Overload zones on fractured neck proximal segment. b) Overload zones on fractured neck distal segment.

was solved as a linear elastic problem. The adequacy of the finite element mesh was verified by maximum principal stress converge within 5% change between subsequent meshes.

The results presented in the study are the maximum principal stresses in the neck. The red region represents the maximum tensile stresses in then stem for a 5320N load (Fig. 4).

1. Discussion

Failure is due to fatigue; however, fatigue is always initiated at point of stress concentration or discontinuity. The manufacturer had changed the Corail stem's neck geometry from matt to polished finish some years ago to extend the fatigue life. Additionally, the neck had flattened in the antero-posterior planes to increase range of motion. The antero-posterior flats are common to a number of manufacturer's necks. Consequently it is believed that something else may have

initiated the fatigue failure in this Corail stem. Similar failures have been reported in the past on titanium stems, authors have attributed failure to overload, geometry, and laser markings.⁴ Other causes for catastrophic failure of a femoral stem are material design, implant positioning (varus alignment) and patient characteristics.^{5–7}

It has been documented in the literature that the anterior and lateral aspect of femoral prostheses are subjected to the greatest tensile stresses during walking, initiating sit to stand, and climbing stairs.⁸ Cracks initiate under tensile stresses. In our case, the manufacturer laser-etched their product codes onto the tensile aspect of the femoral stem. These laser-etchings caused a stress-riser, which initiated the fatigue fracture whilst the patient was gardening in the squatting position. It has been previously described by Lee et al that laser etching at the neck–shoulder junction of the femoral stem causes heat-induced changes in the microstructure as well as an area of local stress.⁹

Fig. 4 – A 3D model of the stem using software program, ANSYS. The 3D model for the stem was generated by removing the hydroxyapatite (HA) from the Corail stem and laser scanning the surfaces. The laser scan data was converted into a 3D solid and imported in the finite element analysis software, ANSYS. The red zone represents the area of greatest tensile stress which correlates with the fracture propagation of the implant (insert).

Woolson et al observed fatigue fractures through etched characters on the anterolateral aspect of femoral stems of all the prostheses that were analysed by the manufacturer using scanning electron microscopes.¹⁰

The affected Corail AMT femoral stems were recalled in February 2004 once DePuy France was aware of multiple incidents of post-operative fatigue fractures through Post Marketing Surveillance.³ Changes in prosthesis design need to be thoroughly tested in a controlled laboratory environment before being offered to surgeons and the community. Catastrophic failures of implants due to poor design and inadequate quality control can have a devastating financial and health impact on the general population.

Conflicts of interest

All authors have none to declare.

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