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Short Communication

Investigation of a fatigue failure in a stainless steel femoral plate

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ABSTRACT

Surgical implants are exposed to severe working conditions and therefore a wide range of failure mechanisms may occur, including fatigue, corrosion, wear, fretting and combinations of them. The mechanical failures of metallic implants may also be influenced by several other factors, including the design, material, manufacturing, installation, post-operative complications and misuse. An 83-year-old patient suffered an oblique femoral shaft fracture due to a fall at home. A stainless steel locking compression plate (LCP) employed in the fracture reduction failed after four months and was sent back to the producer. A second LCP of the same type was implanted and also failed after six months. A failure analysis of the second femoral LCP is performed in this paper. The results demonstrate that poor material quality was decisive to the failure. The chemical analysis revealed a high P content in the steel, which is not in accordance to the standards. A combination of factors lead to LCP fracture and these include: brittle crack initiation due to phosphorus, segregation at grain boundaries, crack propagation due to cyclic loading and final fast fracture favored by the loss of ductility due to cold work.

1. Introduction

The femur is the longest and strongest bone in the human body. The femoral shaft is the lengthy part of the femur, and a break along it is called femoral shaft fracture (Bucholz and Jones, 1991). The annual incidence of midshaft femur fractures was estimated to be approximately 10 per 100,000 person/year. The main causes are high-energy collision due to motor vehicle crash and, in older adults (mainly those over age 75 years), low energy falls. These typically occur in the home and account for 65% of the fractures (Weiss et al., 2009; Hedlund and Lindgren, 1986).

Femur fractures vary greatly, depending on the kind and intensity of the loading that causes the break. One of the most common type of femoral shaft break is the oblique fracture, were the fracture plane is inclined in relation to the bone axis line. Most femoral shaft fractures require surgery to heal. The external fixation is a temporary treatment often adopted when the skin and muscles have been injured. Orthopaedic devices such as the intermedullary nail or a compression plate are used in surgical procedures for internal

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fixation of fractures (Sudhakar, 2005). The latter can be classified as dynamic compression plate (DCP) or locking compression plate (LCP). In both cases, the bone fragments are reduced into their normal alignment and held together with special screws and the plate attached to the outer surface of the bone. Another approach, described as the "biological internal fixation", employs flexible fixators and tolerates some mobility of the interface of fracture (Perren, 2002).

The main difference between the compression plates is that in DCP the screws must be tightened into the holes, resulting in high compressive forces between bone and plate that may cause vascular damage to the undersurface bone tissue. The more recent LCP introduced the combination hole, which allows the load to be transmitted through screw-plate system without compression between plate and bone surface when the conical thread holes are used (Kanchanomai et al., 2008; Stevens and Duis, 2008).

Surgical implants are exposed to severe working conditions, including mechanical loading (cyclic and shock), chemical aggression (body fluids) and the static or dynamic contact between the implant materials or the state of implant-to-bone contact (Azevedo and Hippert, 2002; Roffey, 2012). Therefore, a wide range of failure mechanisms may occur, including fatigue, corrosion, wear, fretting and combinations of them. The mechanical failures of metallic implants may also be influenced by several other factors, including the design, material selection, manufacturing practice, improper installation, postoperative complications and misuse Azevedo and Hippert, 2002. Furthermore, once a foreign material is implanted, the body may react unfavorably, leading to another class of failure,

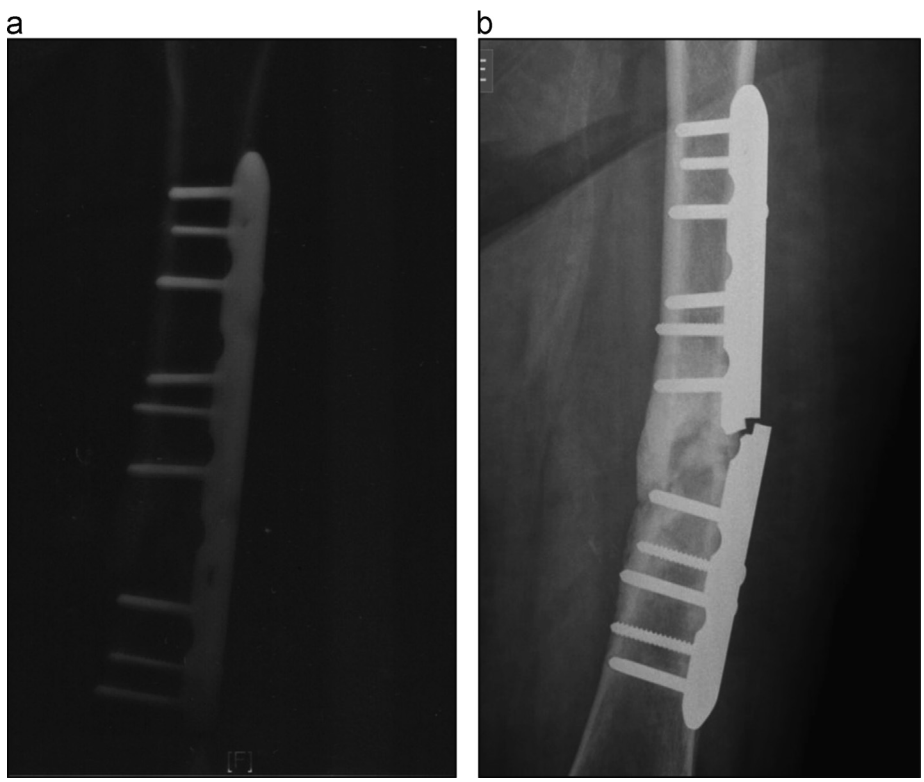

Fig. 1.1 – X-Ray image of second LCP: (a) after implantation; (b) after fracture.

Fig. 1.2 – Fractured LCP (scale in mm).