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Lecture

Biomechanics of a cemented short stem: Standard vs. line-to-line cementation techniques. A biomechanical in-vitro study involving six osteoporotic pairs of human cadaver femurs

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ABSTRACT

Background: Short-stem total hip arthroplasty (THA) potentially offers advantages compared to conventional THA, including sparing bone and soft tissue and being a facilitated and less traumatic implantation. However, the indication is limited to patients with sufficient bone quality. Cemented short-stem THA might provide an alternative to conventional cemented THA. To date, no cemented short stem is available on the market.
Methods: In the present in vitro study, primary stability of a new cemented short stem was evaluated, comparing standard (undersized stem) versus line-to-line (same-sized stem) cementing techniques, using six pairs of human cadaver femurs.

Primary stability, including reversible micromotion and irreversible migration, was assessed in a dynamic material-testing machine. Fracture load was tested and fracture pattern analyzed.
Findings: Both cementation techniques (standard vs. line-to-line) displayed comparable results with respect to primary stability without any statistical differences (micromotion: 17.5 μm vs. 9.6 μm (p = 0.063); migration: 9.5 μm vs. 38.2 μm (p = 0.188)). Regarding fracture load, again, no difference was observed (3670 N vs. 3687 N (p = 0.063)). In all cases, proximal fractures of Vancouver type B3 occurred.
Interpretation: The present in vitro study demonstrates that the line-to-line cementation technique, which is favourable regarding the philosophy of short stem THA, can be further pursued in the course of the development of a cemented short stem. Further investigations should address how well the cemented short stem compares to well-established cemented straight-stem designs.

1. Introduction

Due to demographic changes in American and European populations, an increase in the number of elderly patients with poor bone quality who will need to be treated with total hip arthroplasty (THA) can be expected (Christensen et al., 2009; Ortman et al., 2014). Registry data from recent years show favourable results of cemented THA in terms of revision rates compared to cementless THA, particularly in elderly patients (Hailer et al., 2010; Wyatt et al., 2014). Additionally, in cemented THA, the maximum fracture load is increased compared to cementless THA and the rate of periprosthetic fractures is reduced accordingly (Berry, 1999; Thomsen et al., 2008). Cement fixation in THA already has a 40-year history of success (Knight et al., 2011). However, there is a continuing debate regarding an adequate cementation technique and the resulting cement-mantle thickness (Skinner et al., 2003). In some stem designs, reduced cement-mantle thickness and cement-mantle defects have been associated with early osteolysis (Maloney et al., 1990). Consequently, this led to the generally accepted principle to select an undersized stem, resulting in a cement mantle with a consistent thickness of ≥ 2 mm (Ramos and Simões, 2009; Gunn et al., 2012). Currently, this for most implants represents the standard cementation technique.

However, in France, starting in the early seventies, a surgical technique was developed and used with some stem designs so as to

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Fig. 1. Cemented optimys-stem (Mathys Ltd., Bettlach, Switzerland).

completely contradict this approach (El Masri et al., 2010). A same-sized canal-filling stem is implanted line-to-line by a press-fit technique to achieve direct load transfer from the stem to the bone. Consequently, this results in a thin cement mantle with multiple cement-mantle defects. Surprisingly, excellent survival rates have been reported for THAs implanted by this technique (Erivan et al., 2017; Kerboull et al., 2004). This phenomenon of excellent clinical results obtained with two seemingly contradictory techniques has previously been referred to as the “French paradox” (Langlais et al., 2003).

Short-stem THA has emerged in the recent years. It is considered to potentially offer several advantages compared to conventional THA (Ettinger et al., 2011; Gustke, 2012; Kovacevic et al., 2014; von Lewinski and Floerkemeier, 2015). Short stems allow sparing of bone and soft tissue (Kutzner et al., 2017). Furthermore, given a facilitated and less traumatic implantation technique, intraoperative blood loss can be reduced (Hochreiter et al., 2016). Recent studies provided beneficial mid-term clinical results compared to conventional straight-stem designs with decreased intraoperative complication rates (Kaipel et al., 2015; Molli et al., 2012; van Oldenrijk et al., 2014). However, in cementless short-stem THA, a major concern in reducing diaphyseal fixation by stem shortening is the possible reduction of implant stability (Bieger et al., 2012). Therefore, its application in severe osteoporotic bone cannot be recommended (Shin et al., 2016). Cemented short-stem THA may, therefore, be a possible alternative for patients with poor bone quality. To date, no new-generation short stem, providing cemented fixation, is available on the market. Given the philosophy of new-generation short stems, in cemented short-stem THA the usage of the line-to-line cementation technique can be considered to be preferable and more likely to be feasible, by allowing direct cortical contact and not demanding any centralizing devices.

The aim of this in vitro study was to compare standard versus line-to-line cementing techniques in the course of the development of a cemented calcar-guided short stem, potentially resulting in different cement-mantle thicknesses, assessing the primary stability and maximum fracture load.

The hypothesis was that the line-to-line technique displays equivalent primary stability compared to the standard technique.