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The influence of the twin peg design on femoral Interface temperature and maximum load to failure in cemented Oxford unicompartmental knee arthroplasty

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A R T I C L E I N F O

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A B S T R A C T

Background: The twin peg femoral component was introduced for the cemented Oxford unicondylar knee to increase implant stability. The aim of this experimental study was to investigate the influence of the twin peg design on femoral interface temperature and maximum load to failure in comparison to the single peg design.
Methods: In this experimental study medial Oxford unicompartmental knee arthroplasty was performed in 12 pairs of fresh-frozen human knees. A cemented femoral single peg component was implanted on the one side (group A) and a cemented twin peg component on the other side (group B). Cement interface temperature was continuously monitored during the procedure. Maximum tensile forces of the femoral components were measured by pull-out tests.
Findings: Maximum femoral interface temperatures did not reach critical values for heat necrosis of the bone in group A (mean 28.4, SD 1.2 °C) or group B (mean 27.6, SD 0.5 °C). The maximum load to failure was significantly higher in the twin peg group (mean 3628.41, SD 650.92 N) compared to the single peg group (mean 2979, SD 781 N) ($P = 0.016$).
Interpretation: Our experiments showed higher load to failure for the twin peg design compared to the single peg design without raising the risk of heat necrosis at the interfacial bone. The twin peg component offers a save alternative to the single peg component in a cadaveric setting.

1. Introduction

Aseptic loosening is one of the most common reasons for revision surgery in cemented unicompartmental knee arthroplasty (UKA) (Lewold et al., 1995; Price and Svard, 2010; Saldanha et al., 2007). Aseptic loosening is associated with failure of either the cement-bone or the cement-implant interface or both. An important factor for implant stability is the quality of cement penetration and interdigitation into cancellous bone (Askew et al., 1984; Clarius et al., 2011; Halawa et al., 1978; Krause et al., 1982; MacDonald et al., 1993). In addition to correct cementation technique and bone quality also the prosthesis design influences overall interface strength. The femoral twin peg component was introduced for the cemented Oxford unicondylar knee to increase implant stability. Initially designed as a high flexion unicondylar knee the posterior radius of the component was increased by 15° and an additional peg was added (White et al., 2012). We presumed that these design modifications lead to more stable implant fixation regarding interface strength. However, a potential increase in cement volume between the two pegs could lead to higher interface temperatures during polymerization. This might result in thermal damage and bone necrosis which could potentially compromise implant stability (Borzacchiello et al., 1998; Eriksson and Albrektsson, 1983).

The aim of this study was to investigate the influence of the additional femoral peg on interface temperature during curing of the cement and to assess maximum load to failure of both implant designs in a pull-out test.

2. Methods

We performed medial Oxford unicompartmental knee arthroplasty (OUKA, Oxford® Phase III, Biomet, UK Ltd.) in 12 pairs of fresh-frozen human femora. The study protocol was accepted by the local ethics committee. Preoperative bone mineral density (BMD) was measured by Dual-energy X-ray absorptiometry (DEXA) at the femoral neck using the

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Hologic® QDR-2000 bone densitometer (Hologic® Inc. Bedford, MA, USA). Anteroposterior and lateral radiographs were taken of each femur to rule out possible osteolysis and implant size was chosen according to digital planning (TraumaCad®, Voyant Health, Columbia, USA). With the use of a computer-generated list left and right knees were randomly allocated into two groups. The cemented Oxford single peg femoral component was implanted on the one side (group A, $n = 12$) and a cemented Oxford twin peg component on the other side (group B, $n = 12$). All operations were performed by one surgeon experienced with the OUKA surgical technique (RGB). After preparation and performing the femoral saw cuts the bone bed was cleansed using pulsed bone lavage (OptiLavage®, Biomet, Bridgend, UK) with 500 ml of saline solution stored at room temperature. High viscosity bone cement (Optipac® Refobacin® Plus Bone Cement, Biomet Orthopaedics Switzerland GmbH) was used in both groups after vacuum mixing (Optivac® Vacuum Mixing System, Biomet Cementing Technologies AB, Sweden) at a mean room temperature of 20.0 °C, SD 0.4 °C and humidity of 31.4%, SD 17.8%. All specimens were preheated to 37 °C prior to implantation of the femoral components in order to simulate body temperature. The bone surface temperature was measured with an infrared thermometer (Inspacto 900plus, Infrapoint, Saalfeld, Germany) before applying the bone cement. The mean surface temperature before cement application was 23.9 °C, SD 0.9 °C. This temperature corresponds to the surface temperature of the femoral condyle that was measured in vivo during surgery after bone preparation and lavage (Clarius et al., 2009; Clarius et al., 2011). Interface temperature was continuously monitored with a temperature probe (length, 100 mm; diameter, 1.6 mm; model Pt100; B + B Thermotechnik GmbH, Donaueschingen, Germany) during curing of the cement. We designed a special fixation guide that was locked onto the spigot system in order to place the temperature probe 5 mm under the bone surface and right in the middle of the two pegs (Fig. 1). The bone cement was applied 2 min and 30 s after starting mixing. It was pressurized in the central peg hole with a cement gun and a layer of cement was spread on the surface of the femoral component. After impacting the implant with the use of a light mallet a constant compression force of 180 N (Clarius et al., 2011) was applied by a linear motor (ET100, Parker Hannifin GmbH & Co. KG Electromechanical Automation, Offenburg, Germany) at a knee flexion angle of 45° over a period of 16 min and 30 s during curing of the cement. After implantation the specimens were molded in polyurethane (RenCast™ FC 53 Polyol/FC 53 Isocyanate; Huntsman, Salt Lake City, UT, USA). The weight of the bone cement in the vacuum mixing system was measured before and after surgery and the amount of cement applied to the bone was calculated. Standardized anteroposterior and lateral radiographs of the specimens were taken postoperatively to ensure correct implant position. A vertical pull-out test was performed with a material testing machine (Zwick GmbH & Co. KG, Ulm, Germany). The pull-out force vector was oriented in the central peg direction (Fig. 2a and b). Testing was performed under displacement control at a rate of 2.0 mm/min until implant failure occurred and the maximum pull-out force was measured.

Statistical evaluation was performed with IBM® SPSS® Statistics for Windows®, version 22.0 (SPSS Inc., Chicago, IL, USA). The Shapiro-Wilk test showed normal distribution. Data were evaluated descriptively as arithmetic mean, standard deviation, minimum and maximum. The paired t-test was used for comparing the mean differences of both groups. All tests were two-sided and the level of significance was set at $P < 0.05$.

3. Results

Mean BMD (t-score) of the specimens was −0.27 (SD 1.03) in the single peg group and −0.35 (SD 0.96) in the twin peg group. No statistically significant difference in BMD was found between the two groups ($P = 0.415$). No difference in the amount of cement that was applied during surgery was found between the two groups (mean 7.5 g (SD 1.9 g) in group A and 7.67 g (SD 0.8 g) in group B, $P = 0.761$). The absolute maximum interface temperature measured was 30.2 °C. Femoral interface temperature was higher in the single peg group (mean 28.4 °C, SD 1.2 °C) compared to the twin peg group (mean 27.6 °C, SD 0.5 °C) ($P = 0.035$) (Fig. 3a). Pull-out force was significantly higher in the twin peg group (mean 3628 N, SD 651 N) than in the single peg group (mean 2979 N, SD 781 N) ($P = 0.010$) (Table 1) (Fig. 3b).

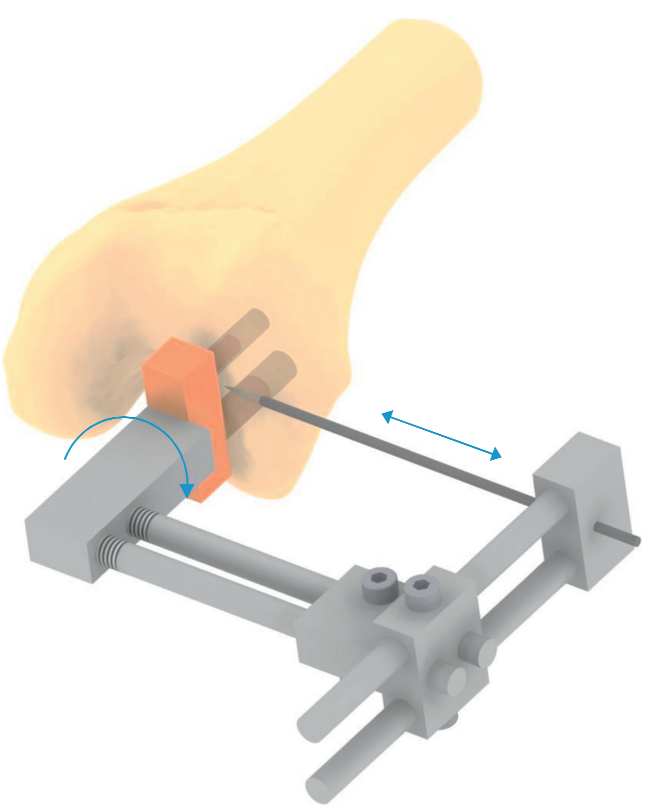

Fig. 1. Illustration of the fixation guide that was used in order to place the temperature probe right in the middle between the two pegs and 5 mm under the bone surface. The device could be used for all sizes of component. It was locked onto the spigot system and rotated up to final position. Bone was opened by drilling a hole with a Kirschner-wire of the same diameter as the temperature probe.

4. Discussion

Despite excellent mid and long term results of cemented unicompartimental knee arthroplasty (Isaac et al., 2007; Murray et al., 1998; Pandit et al., 2011; Pietschmann et al., 2014; Svard and Price, 2001; Vorlat et al., 2006) aseptic loosening remains one of the major reasons for revision surgery (Lewold et al., 1995; Price and Svard, 2010; Robb et al., 2013; Saldanha et al., 2007). Even though loosening of the femoral component can be difficult to diagnose because the interface is hardly seen on radiographs (Monk et al., 2009) aseptic loosening of either the femoral or tibial component accounts for up to 45% of revision surgery in UKA according to joint registry data (Australian Orthopaedic Association, 2014; The Swedish Knee Arthroplasty Register, 2014). It is usually associated with failure of the cement-implant or the cement-bone interface and a result of poor initial fixation (Seeger et al., 2013; Goodfellow et al., 2002). For the oxford unicompartmental knee arthroplasty a twin peg component was introduced to increase primary fixation strength of the prosthesis (White et al., 2012). By the additional peg and the larger articulating radius the surface area under the implant increases from 1696 mm^2 to 1849 mm^2 for a medium sized femoral component and from 1939 mm^2 to