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Cement applicator use for hip resurfacing arthroplasty

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A B S T R A C T

We compared the manufacturer recommended cementing technique for a femoral hip resurfacing implant (BHR, S&N) to a newly designed cement applicator on 20 porous carbon foam specimens. Substantial design changes and improvements of the cement applicator were necessary: The diameter and number of the cement escaping holes at the top of the applicator were optimized for medium viscosity cement. It was necessary to add four separate air inlet holes with large diameters. The inner shape of the applicator had to be adapted to the BHR design with a circular extending chamfer in the proximal region, a parallel inner wall and a second chamfer distally.

The interface temperatures showed no risk for heat necrosis using both techniques. The cement penetration depth was more uniform and significantly reduced for the applicator cementing technique (4.34 ± 1.42 mm, 6.42 ± 0.43 mm, $p = 0.001$). The cement-applicator showed no cement defects compared to a large defect length (0.0 ± 0.0 mm, 10.36 ± 1.10 mm, $p < 0.001$) with the manufacturer recommended cementing technique.

The cement applicator technique appears to be effective for a homogenous cement distribution without cement defects and safe with a lower risk of polar over-penetration.

1. Introduction

Different failure mechanisms have been documented for hip resurfacing arthroplasty [1-6]. A prospective study of 5000 Birmingham Hip Resurfacings (BHR; Smith & Nephew Orthopaedics, Warwick, United Kingdom) showed that the 56.6% of failures occurred on the femoral side [7]. A study of 98 metal-on-metal surface arthroplasty implant retrievals showed a higher cement penetration in loosened components [1]. Not only an excessive cement penetration but also inadequate and poor cementations are common causes of failure [8]. The implant design has thereby a significant influence on the cementing results and the cemented interface temperatures [9]. This showed the implant sensitivity to changes of the cementing technique [9]. There is a distinction between cement filling and cement packing techniques in the cementation of hip resurfacing implants [10-12]. Compared to cement packing techniques, the use of cement filling with different cement viscosities showed an increase in cement penetration [13]. An increased cement penetration under the femoral component induces higher bone and interface temperatures, which can lead to thermal necrosis [4]. Retrieval analyses could show that the newer cement packing techniques and higher cement viscosities could be helpful in preventing over penetration of bone cement [14]. Bitsch et al. showed that a prototype of a cement applicator tool reduces cement defects and over penetration while providing a more consistent initial stability compared to a cement filling technique for the articular surface replacement (ASR; DePuy Orthopaedics) and high viscous bone cement [15]. However whether this applicator technique has comparable results with the different implant geometry of the Birmingham Hip Resurfacing (BHR; Smith & Nephew) and a medium cement viscosity is unclear. In addition, the femoral cement penetration could be influenced by many other parameters including lavage technique, bone mineral density, cementation timing, cement viscosity and the amount of cement. It takes a lot of experience to compensate for all these parameters with the different techniques available. The cement applicator was developed to optimize cement distribution on the reamed femoral head and make cementing safer, especially for beginners.

The aim of the study was to compare the newly designed cement applicator with the manufacturer-recommended cementing techniques for the BHR under standardized conditions.

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2. Materials and methods

2.1. Bone model

We used 20 cancelated carbon foam specimens (RVC foam; ERG Materials and Aerospace, Oakland, Calif) as substitutes for human femoral heads to compare the manufacturer-recommended BHR cementing technique with a new cement-applicator. The synthetic femoral heads were double compressed with 1.2 pores per millimeter and 6% density similar to the trabecular structure of human femoral heads. The carbon foam specimens were manufactured with the geometry of the prepared and reamed femoral head of the size 48 mm. The geometry was checked prior to the test with the help of the original instruments.

The specimens were filled with commercially available fat (Bechem Rhus FA 37; Carl Bechem GmbH, Hagen, Germany) to simulate bone marrow. To do this, the carbon specimens were placed with the fat filling in a fitting cylindrical syringe container. Manual pressure was applied to the syringe under visual control and the fat was pressed into the specimens. The fat filled carbon foams were irrigated with high pressure pulsed lavage (Scandimed, Biomet Merck, Sweden). The application was carried out for a period of 30 s for the top, followed by another 60 s for the chamfer and the wall, resulting in a total amount of 1125 ml of saline solution. Following the lavage, all specimens were dried with gauze sponges, as is commonly done during surgery. Bitsch et al. demonstrated that fat-filled cancelated carbon foam specimens properly emulate human femoral heads for resurfacing. The cement penetration resistance and thermal properties showed no significant difference between the carbon foam material and human femoral heads for resurfacing [16]. One important detail of the modelling with cancelated carbon foam was to adjust the surface temperature of the specimens prior to cementation. In vivo measurements showed a mean surface temperature of the femoral head after jet lavage and before cementation of 23.2 ± 0.7 °C [15]. This temperature is significantly lower than physiologic body temperature. The carbon foam specimens were slowly warmed up to body temperature using an incubator (Function Line, Heraeus Holding GmbH, Hanau, Germany). The cementation was started after a cool down of the carbon foam specimens' surface to 23 °C.

2.2. Measuring temperature and pressure

Cement penetration pressures (CPP) and interface temperatures were measured during both cementation and polymerization. The CPP was measured at three different points of the implant (Fig. 1). Therefore screw threads were reamed into the BHR components to fix the pressure probes (XPM5/XAM; FGP Sensors, Les Clayes sous Bios Cedex, France). Polymerization temperature at the interface was measured 5 and 15 mm under the foam surface (Fig. 2). The foam specimens were mounted in a fixture frame with an integrated port for temperature probe fixation. The temperature probes were inserted through the two port terminals (5 mm and 15 mm) into the carbon foam specimens and secured by a clamp. The stability of the temperature probes is similar to that of a K-wire. The temperature probes used were platinum resistance thermometers (Pt 100, B+B Thermo-Technik, Donaueschingen, Germany). All data were recorded in real time using custom-made data logging software (Tep_Force 1.0, Orthopeadic University Hospital, Heidelberg, Germany) and a USB data acquisition device (National Instruments-NI-BOX-DAQ-PAD-6015, National Instruments, Dublin, Ireland).

2.3. Bone cement and cement mixing

The medium viscous bone cement for both investigated cementing techniques was Simplex P (Stryker GmbH & Co. KG, Duisburg,

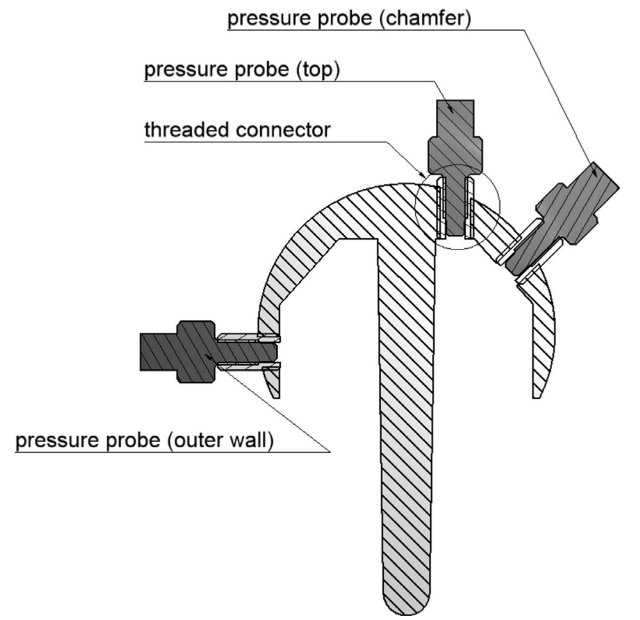

Fig. 1. The cement penetration pressure (CPP) was measured at three different points in the implant; therefore, screw threads were integrated into the femoral component to fix the pressure probes at the top, at the chamfer, and at the wall.

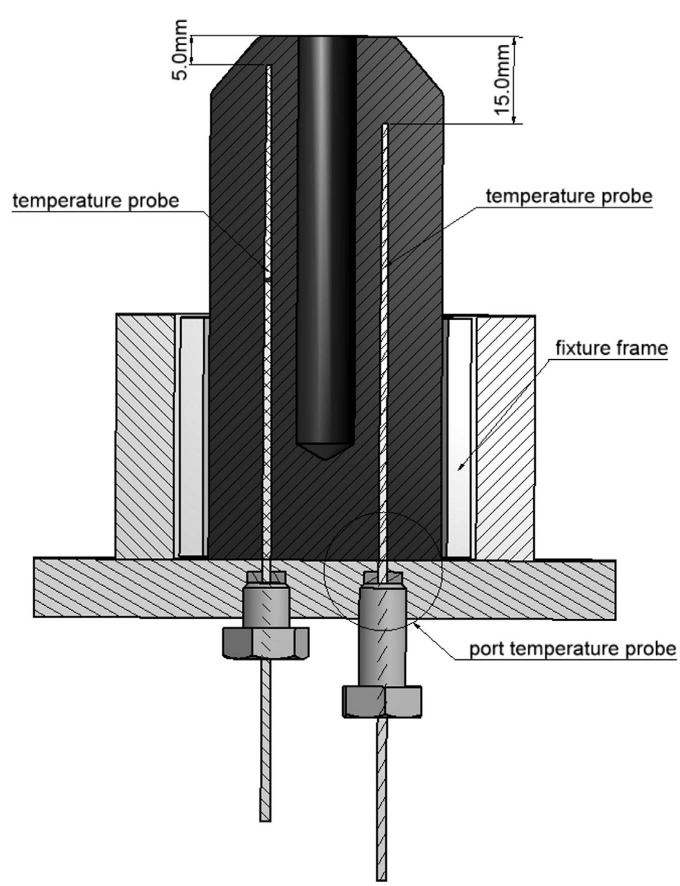

Fig. 2. Fixation device with mounted foam specimen and ports for the temperature probes with integrated sensors. Polymerization temperatures at the interface were measured 5 and 15 mm under the foam surface. The temperature probes used were platinum resistance thermometers.