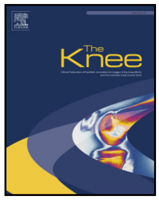
The Knee xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

The Knee



Effect of lavage and brush preparation on cement penetration and primary stability in tibial unicompartmental total knee arthroplasty: An experimental cadaver study

Christian Scheele [a,*], Matthias F. Pietschmann [a], Christian Schröder [a], Thomas Grupp [a,b], Melanie Holderied [b], Volmar Jansson [a], Peter E. Müller [a]

[a] Department of Orthopedic Surgery, Physical Medicine and Rehabilitation, University Hospital, Ludwig Maximilians University (LMU), Campus Großhadern, Marchioninistraße 15, 81377 Munich, Germany
[b] Aesculap AG Research & Development, Am Aesculap-Platz, 78532 Tuttlingen, Germany

ARTICLE INFO

Article history:
Received 22 May 2016
Received in revised form 22 August 2016
Accepted 16 September 2016
Available online xxxx

Keywords:
Cement penetration
Primary stability
Pulsed lavage
Unicompartmental knee arthroplasty
Brush preparation

ABSTRACT

Background: Unicompartmental total knee arthroplasty (UKA) is a well-established treatment option for unicondylar osteoarthritis, and generally leads to better functional results than tricompartimental total knee arthroplasty (TKA). However, revision rates of UKAs are reported as being higher; a major reason for this is aseptic loosening of the tibial component due to implant–cement–bone interface fatigue. The objective of this study was to determine the effects of trabecular bone preparation, prior to implantation of tibial UKAs, on morphological and biomechanical outcomes in a cadaver study.

Methods: Cemented UKAs were performed in 18 human cadaver knees after the bone bed was cleaned using pulsed lavage (Group A), conventional brush (Group B) or no cleaning at all (Group C, control). Morphologic cement penetration and primary stability were measured.

Results: The area proportion under the tibial component without visible cement penetration was significantly higher in Group C (21.9%, SD 11.9) than in both Group A (7.1%, SD 5.8), and Group B (6.5%, SD 4.2) ($P = 0.007$). The overall cement penetration depth did not differ between groups. However, in the posterior part, cement penetration depth was significantly higher in Group B (1.9 mm, SD 0.3) than in both Group A (1.3 mm, SD 0.3) and Group C (1.4 mm, SD 0.3) ($P = 0.015$). The mode of preparation did not show a substantial effect on primary stability tested under dynamic compression-shear test conditions ($P = 0.910$).

Conclusion: Bone preparation significantly enhances cement interdigitation. The application of a brush shows similar results compared with the application of pulsed lavage.

1. Introduction

Unicompartmental total knee arthroplasty (UKA) is a well-established treatment modality for anteromedial osteoarthritis, with reported 10-year survival rates up to 98% [1,2], 15-year rates up to 96% [2], and 20-year rates up to 91% [3]. Steele et al. reported a

* Corresponding author.
E-mail address: C-Scheele@web.de (C. Scheele).

http://dx.doi.org/10.1016/j.knee.2016.09.015
0968-0160/

25-year survival rate of 80% [4]. In addition to good survivorship, various studies have demonstrated excellent functional results, with a range of advantages, compared with tricompartmental total knee arthroplasty (TKA) [5,6].

However, large register studies like the Swedish Knee Arthroplasty Register, the Australian Orthopaedic Association and the Kaiser Permanente Registry (Oakland, CA, USA) have indicated higher revision rates for UKAs than for TKAs [7–9]. The predominant mode of failure is loosening of the tibial component; [10] this means a fatigue of the implant–cement–bone interface created at the time of the initial operation. Therefore, a strong interface that can resist the applied shear forces and load is crucial for delivering sustainable outcomes [11].

Cleaning the resection surface is generally considered as a prerequisite for adequate cement penetration and interlocking [12–16]. The application of bone cement onto a clean surface that is free of blood, bone marrow and debris improves the morphological interlocking of the cement and, thereby, the biomechanical strength of the interface [11–13,15,17–19].

The present study was conducted to assess the impact of bone surface preparation, via pulsed lavage or mechanical brush, prior to implantation of tibial UKA components, versus a control group (no bone preparation), on morphological cement penetration and primary biomechanical stability under dynamic compression-shear loading conditions in human tibiae. It was presumed that both the application of pulsed lavage and brush would increase cement penetration and primary stability of the implant–cement–bone interface. It is believed that, to date, no experimental studies about bone preparation using a brush in UKAs have been published.

2. Methods

The local ethics committee accepted the study concept. Unicompartmental total knee arthroplasties were implanted in 18 fresh–frozen human tibiae through an open surgical approach. Mean donor age was 72.2 years, ranging from 53 to 90 years (for distribution of specimen in groups see Table 1).

To determine bone mineral density (BMD) and exclude specimens with osseous abnormalities, CT-scans (Sensation 64 Somatom, Siemens AG Munich, Germany) were performed for all 18 tibiae. The BMD was determined on the tibial head in seven layers of one-millimeter thickness, measured every three millimeters, using relative calibration to water (0 HU) and calcium (200 HU). Afterwards, the tibiae were divided into three groups of comparable BMD.

The proximal third of fresh–frozen human tibiae were stored at −20 °C and thawed for at least 48 h at seven degrees centigrade. An experienced surgeon, using an open surgical approach and following the guidelines of the manufacturer's manual, implanted the UKAs. The bone preparation was carried out differently in the three groups: in Group A, the resection surface was cleaned using pulsed lavage (500 ml, two minutes of purging time, Pulsavac® Plus, Zimmer, Warsaw, USA); in Group B, preparation was performed using a brush (cleaning brush nylon, item number M-16, Medical Instruments Corporation GmbH, Herford, Germany); and Group C was designed as the control group without any preparation of prior cemented implantation of the tibial components (Univation® F, Aesculap Tuttlingen, Germany). After the appropriate implant size was determined, horizontal resection was performed (seven millimeters below the joint line) with an anatomical posterior slope. High viscosity bone cement (Palacos® R 20 g powder/10 ml monomer, Heraeus Medical Wehrheim, Germany) was chosen for fixation of the tibial implants and mixed manually. Approximately 10 g of cement was applied onto the inferior surface of the tibial prosthesis, while the tibial surface was left uncemented (single-layer cementing technique). Each tibial tray was carefully placed and impacted onto the tibia using a specific impactor (Univation® F instruments, Aesculap, Germany). Manual pressure of the implant along the long axis of the tibia was maintained during the polymerization process of the bone cement. After removal of the surrounding soft tissue, the specimens were aligned in the sagittal plane to the tibial axis in 0° extension, and imbedded with polyurethane casting resin in metal cylinders.

To assess the primary stability of the implant–cement–bone interface, the tibiae were fixed on the hydraulic testing machine in a flexed position to simulate peak joint loading during mid-stance phase at 15° flexion in the walking gait cycle [20–23]. During the dynamic compression-shear testing, an initial tibio-femoral load of 1500 N was applied for 1000 cycles, followed by a stepwise load increase of 300 N for each 1000 cycles, until failure of the specimen or termination of the test at the highly demanding final load level of 4200 N occurred. The criterion of failure was set to a maximal movement increase in the medial knee joint articulation of 0.4 mm at a single load level. This leads to minor injury of the implant–cement–bone interface where the implants remain on the bone; therefore, the subsequent morphologic analysis was still possible.

To morphologically analyze the cement layer, the specimens were dissected in the sagittal plane in the region of the eminentia intercondylaris and the transversal plane 20 mm below the tibial plateau, and imbedded (Technovit 4004, Heraeus Medical

Table 1
Cadaver specimens were divided into three groups of comparable bone mass density (BMD). The table displays gender composition, age distribution and bone density (measured as BMD on the overall tibial head and as Hounsfield units of the lateral plateau only).

	Pulsed lavage	Brush	No cleaning
Number of knees (left/right)	6 (3/3)	6 (1/5)	6 (4/2)
Gender (male/female)	4/2	5/1	5/1
Age, years (min–max)	72.2 (53–84)	70.3 (53–90)	74.2 (53–90)
Trabecular bone mass density, mg(Ca^{2+}HA)/mm^3	94.1 ± 21.4	113.3 ± 41.1	103.3 ± 26.0
Bone mass density (>/<100 mg(Ca^{2+}HA)/mm^3)	2/4	3/3	3/3
Hounsfield units (lateral plateau of the tibia only)	132.3 ± 36.0	148.7 ± 50.3	136.0 ± 38.7

Please cite this article as: Scheele C, et al, Effect of lavage and brush preparation on cement penetration and primary stability in tibial unicompartmental total knee arthropla..., Knee (2016), http://dx.doi.org/10.1016/j.knee.2016.09.015