Clinical Biomechanics 28 (2013) 904–909

Contents lists available at ScienceDirect

Clinical Biomechanics

journal homepage: www.elsevier.com/locate/clinbiomech

Increase of tibial slope reduces backside wear in medial mobile bearing unicompartmental knee arthroplasty

Patrick Weber *, Christian Schröder, Florian Schmidutz, Michael Kraxenberger, Sandra Utzschneider, Volkmar Jansson, Peter E. Müller

Department of Orthopedic Surgery, University Hospital, Ludwig-Maximilians-University (LMU), Campus Grosshadern, Marchioninistr. 15, 81377 Munich, Germany

ARTICLE INFO

Article history:
Received 29 July 2013
Accepted 22 August 2013

Keywords:
Unicondylar knee arthroplasty
Wear
Knee simulator
Mobile bearing
Tibial slope

ABSTRACT

Background: Unicondylar knee arthroplasty is a good alternative for patients in monocompartmental osteoarthritis. The revision rate in unicondylar knee arthroplasty is higher than in total knee arthroplasty. The influence of the tibial slope on wear in unicondylar knee arthroplasty has not been investigated so far.
Methods: The influence of the tibial slope on wear was investigated in mobile bearing unicondylar knee prosthesis. This was positioned with four different tibial slopes (−4°, 0°, 4°, 8°) in a knee wear simulator simulating the human gait in a plane according to ISO 14243-2:2002(E). After this a kinematic analysis was performed and the inlays were observed under reflected-light-microscopy.
Findings: Wear was significantly reduced with an increasing tibial slope (0°: 3.46 mg/million cycles, SD: 0.59, 4° slope: 1.52 mg/million cycles, SD: 0.06, 8° slope group: 0.99 mg/million cycles, SD: 0.42). An anterior slope of −4° also reduced wear (2.08 mg/million cycles, SD: 0.37). Kinematic analysis revealed a reduced translation between the inlay and the tibia with an increasing tibial slope. The backside of the inlays of the 4° and 8° slope group showed less wear pattern when observed under reflected-light microscopy.
Interpretation: Increasing the tibial slope led to a reduced translation between the inlay and the prosthesis in the analysed mobile-bearing unicondylar knee arthroplasty and with this to a reduced backside wear. A tibial slope between 4 and 8° can be recommended in mobile UKA to reduce wear, however, the influence on the ligaments has to be considered and needs to be investigated in further studies.

1. Introduction

Unicompartmental knee arthroplasty (UKA) in patients with isolated medial osteoarthritis of the knee is nowadays a standard procedure with good results (Price and Svard, 2011). However, the results are discussed controversially and the survival rate of the unicompartmental knee prostheses is inferior to that of total knee prostheses (Labek et al., 2011; The-Swedish-Knee-Arthroplasty-Register, 2010). The failure of UKA has several reasons; wear and loosening are responsible for more than 50% of the revisions (The-Swedish-Knee-Arthroplasty-Register, 2010). Reducing wear is therefore a major issue in improving the longevity of UKA. In vitro wear simulation is nowadays a standard procedure to evaluate wear at different conditions in knee arthroplasty and alternate materials or different designs have shown different amount of wear in UKA (Grupp et al., 2010; Kretzer et al., 2011; Schroeder et al., 2013).

The influence of the positioning of UKA on wear has not been evaluated so far. In general there is little evidence about the optimal positioning of the UKA as this has only been investigated in very few studies (Hernigou and Deschamps, 2004; Sawatari et al., 2005). In most UKA mobile bearing designs the femoral component has a spherical surface and therefore its positioning is not so crucial. Furthermore, loosening of the femoral component is rarer compared to that of the tibial component (Riebel et al., 1995). So the positioning of the tibial component has more influence on knee kinematics after UKA implantation. The role of the tibial slope in knee surgery has gained a lot of attention in total knee arthroplasty and in high tibial osteotomy (Bellemans et al., 2005; Fujimoto et al., 2012; Jojima et al., 2004).

The role of the tibial slope during the implantation of an UKA has not been investigated so far. The manufacturers of UKAs recommend positive tibial slopes with values between 10° positive slope and 5° negative slope (Weber et al., 2013). In a pilot study the role of the tibial slope on wear in a UKA was evaluated and a proof of principle was performed. It was shown that a medial tibial slope of 8° led to a reduced wear in vitro compared to 0° slope (Weber et al., 2012).

The first aim of this study was to investigate further tibial slope positions and the second aim was to analyse the reason of the observed reduced wear rate by kinematic and wear particle analysis.

The first hypothesis was that the higher slope led to a reduced movement between the tibia and the femur and with this to a reduced wear. The second hypothesis was that the generated wear particles would not differ in size and shape.

* Corresponding author at: Department of Orthopedic Surgery, Campus Grosshadern, Ludwig-Maximilians-University, Marchioninistr. 15, 81377 Munich, Germany.
E-mail address: patrick.weber@med.uni-muenchen.de (P. Weber).

0268-0033/$ – see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.clinbiomech.2013.08.006

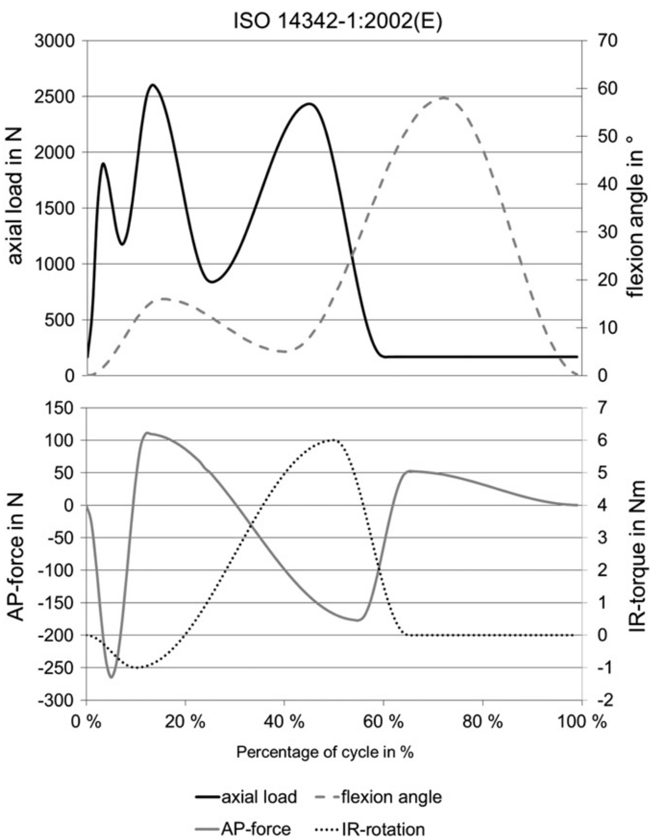

Fig. 1. Load and displacement parameters for the knee wear simulator showing the applied force and displacement waveforms during 1 walking cycle according to ISO 14243-1.

2. Methods

2.1. Prosthesis

In vitro wear simulation of highly conforming mobile-bearing unicompartmental knee prosthesis (Univation®, Aesculap, Tuttlingen, Germany) was performed. The spherical formed femoral component (size F3) of the prosthesis was made of cast CoCr29Mo alloy, the planar tibial tray (size T4) of forged CoCr29Mo alloy, and tibial inserts were made of UHMWPE (GUR 1020; beta-irradiated with 30 kGy). The thickness of the tibial inserts was 7 mm at the edge and 3 mm in the centre as those were fully congruent to the femoral and tibial surface.

2.2. Wear testing

The medial prostheses were submitted to wear testing with four different tibial slopes: −4° (anterior tibial slope), 0°, 4°, and 8° (n = 3 for each group) to cover the values for the range of the tibial slope of −5°–10° proposed by the manufacturers (Weber et al., 2013). The axis of rotation in the sagittal plane was the bisector of the anterior–posterior length of the tibial component. The lateral tibial slope remained unchanged (0° for every group).

The prostheses were loaded with a customized four-station servo-hydraulic knee wear simulator (EndoLab GmbH, Thansau, Germany) reproducing exactly the walking cycle as specified in ISO 14243-1:2002(E) (Fig. 1). We performed a total of 5.0 million cycles for every different slope. Diluted new born calf serum (Biochrom AG, Berlin, Germany) was used as an artificial synovial fluid (Protein contend 30 g/l) and was changed every 500,000 cycles. Before the test, EDTA (AppliChem, Darmstadt, Germany) and Amphotericin B (Biochrom, Berlin, Germany) were added to the test lubricant to avoid PH-variability and fungi growth.

The wear rate was determined gravimetrically using an analytical balance (Sartorius BP211D, Germany) with an accuracy of 0.01 mg every 500,000 cycles according to the ISO 14243-2. Additionally their masses were corrected with the load-soak control and air buoyancy.

2.3. Implant kinematic analysis and reflect-light microscopy

Analysis of the kinematic data like the ap-translation was performed for a mean of ten full gait cycles at 5.0 mio cycles. The cumulative ap-translation was defined as the ap total of the ap-movement between the femur and the tibia.

Furthermore the wear surface of the inserts was analysed by reflected-light microscopy (Leica MacroFluo, Leica Microsystems, Heerbrugg, Switzerland), the used camera was an AxioCam HRc, (Carl Zeiss Microscopy GmbH, Göttingen, Germany).

2.4. Wear particle characterization

Test lubricant out of the wear simulator was stored for wear particle isolation and analysis as described previously (Utzschneider et al., 2009). The lubricants from 1 mio cycles were digested with 37%

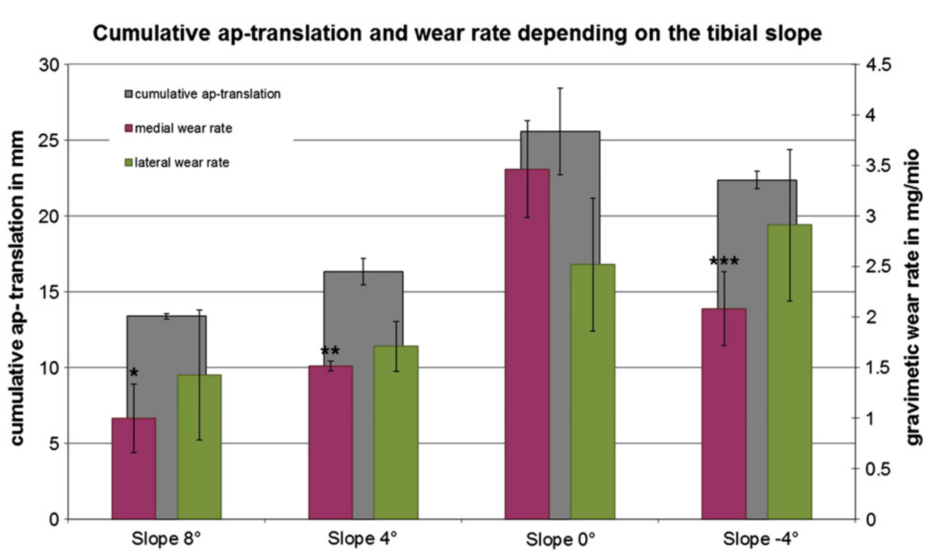

Fig. 2. Wear rate (in mg/million cycles) and ap-movement between the femur and the tibia in function of the tibial slope million of the medial compartment. *, ** and *** = statistically significant ($P < 0.01$, Bonferroni's multiple comparison test).