Journal of Biomechanics 44 (2011) 2724–2727

Contents lists available at SciVerse ScienceDirect

Journal of Biomechanics

journal homepage: www.elsevier.com/locate/jbiomech
www.JBiomech.com

Short communication

The robustness and accuracy of *in vivo* linear wear measurements for knee prostheses based on model-based RSA

E.A. van IJsseldijk [a,*], E.R. Valstar [a,b], B.C. Stoel [c], R.G.H.H. Nelissen [a], J.H.C. Reiber [c], B.L. Kaptein [a]

[a] Biomechanics and Imaging Group, Department of Orthopaedics, Leiden University Medical Center, PO Box 9600, 2300 RC Leiden, The Netherlands
[b] Department of Biomechanical Engineering, Faculty of Mechanical, Maritime, and Materials Engineering, Delft University of Technology, Delft, The Netherlands
[c] Division of Image Processing, Department of Radiology, Leiden University Medical Center, Leiden, The Netherlands

ARTICLE INFO

Article history:
Accepted 13 August 2011

Keywords:
Measurement techniques
RSA
Total knee arthroplasty
Polyethylene wear
Knee joint: imaging

ABSTRACT

Accurate *in vivo* measurements methods of wear in total knee arthroplasty are required for a timely detection of excessive wear and to assess new implant designs. Component separation measurements based on model-based Roentgen stereophotogrammetric analysis (RSA), in which 3-dimensional reconstruction methods are used, have shown promising results, yet the robustness of these measurements is unknown. In this study, the accuracy and robustness of this measurement for clinical usage was assessed. The validation experiments were conducted in an RSA setup with a phantom setup of a knee in a vertical orientation. 72 RSA images were created using different variables for knee orientations, two prosthesis types (fixed-bearing Duracon knee and fixed-bearing Triathlon knee) and accuracies of the reconstruction models. The measurement error was determined for absolute and relative measurements and the effect of knee positioning and true seperation distance was determined. The measurement method overestimated the separation distance with 0.1 mm on average. The precision of the method was 0.10 mm (2*SD) for the Duracon prosthesis and 0.20 mm for the Triathlon prosthesis. A slight difference in error was found between the measurements with 0° and 10° anterior tilt. (difference = 0.08 mm, $p = 0.04$). The accuracy of 0.1 mm and precision of 0.2 mm can be achieved for linear wear measurements based on model-based RSA, which is more than adequate for clinical applications. The measurement is robust in clinical settings. Although anterior tilt seems to influence the measurement, the size of this influence is low and clinically irrelevant.

1. Introduction

Total knee arthroplasty (TKA) is highly successful in relieving pain and restoring joint function, yet implant failure remains a problem. One of the main causes of failure is excessive polyethylene wear. Wear particles can induce osteolysis that may provoke complications such as aseptic loosening. It has been reported that wear and osteolysis are the primary indications for revision in more than 44% of all revisions performed more than two years after surgery (Sharkey et al., 2002).

Excessive wear is related to the design of a prosthesis(Dennis and Komistek, 2006). Therefore, new prosthesis designs are assessed with knee simulator studies before market introduction. Unfortunately these studies are limited in incorporating important factors such as patient activity and the incidence of misalignment (Lavernia et al., 2001; Naudie et al., 2007).

As an alternative, model-based Roentgen stereophotogrammetric analysis (MBRSA) may be used to assess wear in a clinical setting. This imaging and analysis method achieves sub-millimeter precision in assessing migration of prostheses (Garling et al., 2005; Nelissen, 1995; Nilsson and Kärrholm, 1996; Soballe et al., 1993), which is used to predict prosthetic loosening (Ryd et al., 1995). Wear measurements can be obtained with MBRSA and high accuracies were already obtained (Gill et al., 2006; Kellett et al., 2004; Short et al., 2005). However, validation of these wear measurements has been restricted to individual prostheses or measurement protocols. The method's robustness to variations in patient positioning has not been characterized.

The goal of this study is to determine the robustness of TKA wear measurements in MBRSA. The study uses an RSA setup and a knee phantom in which the separation distance between the tibia and femur is known exactly. The measurement method is applied for different settings such as prostheses type, actual separation distance, digital model accuracy and patient positioning. The robustness of the method is determined by assessing the measurement error as a function of these parameters.

2. Materials and methods

We now describe the phantom setup, the MBRSA analysis and the details of the separation measurements that were used in this study.

* Corresponding author. Tel.: +31 71 5261566; fax: +31 6 14449813.
E-mail address: e.a.van_ijsseldijk@LUMC.nl (E.A. van IJsseldijk).

0021-9290/$ - see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.jbiomech.2011.08.013