The Knee 22 (2015) 18–23

Contents lists available at ScienceDirect

The Knee

Variations in morphological characteristics of prostheses for total knee arthroplasty leading to kinematic differences

Xiaojun Shi, Zongke Zhou, Bin Shen, Jing Yang, Pengde Kang, Fuxing Pei *

Orthopaedic Department, West China Hospital, Sichuan University, 37 Guo-xue Lane, Wu-hou District, Chengdu, China

ARTICLE INFO

Article history:
Received 31 May 2014
Received in revised form 10 October 2014
Accepted 30 October 2014

Keywords:
Total knee arthroplasty
Kinematics
Fluoroscopic analysis
Fixed bearing

ABSTRACT

Background and purpose: The aim of this study is to compare kinematics during weight-bearing deep knee-bending motion in patients after bilateral total knee arthroplasty (TKA) of two types: 1) a conventional ScorpioFlex prosthesis and 2) a contemporary redesigned non-restrictive-geometry (NRG) prosthesis installed by the same surgeon.
Methods: We enrolled 15 patients who underwent conventional ScorpioFlex posterior-stabilised TKA in one knee and contemporary NRG TKA on the contralateral side (the same surgeon). During fluoroscopic examination, each patient performed weight-bearing deep knee bending. Motions among all components were analysed using a two- to three-dimensional registration technique.
Results: The mean maximum flexion was 108° (SD 8) and 120° (SD 9) after ScorpioFlex and NRG TKAs, respectively; there were statistically significant differences between the groups. From extension to maximal flexion, the medial condyle translated by 4.8 mm (SD 1.2) and 5.4 mm (SD 2.4) posteriorly after ScorpioFlex TKA and NRG TKA, respectively. The lateral femoral condyle moved 8.4 mm (SD 1.5) and 12.2 mm (SD 2.1) posteriorly after ScorpioFlex TKA and NRG TKA, respectively. There were no significant differences in medial condyle translation between the groups except for the lateral condyle. The total amount of tibial axial rotation during extension to flexion was 5.1° (SD 1.8) after ScorpioFlex and 13.2° (SD 3.4) after NRG TKAs; there were statistically significant differences between the groups.
Conclusions: NRG resulted in much better maximum flexion, lateral condyle movement and tibial internal rotation than did ScorpioFlex TKAs. The observed kinematic differences are most likely caused by variations in the morphological characteristics of the two implants.
Level of evidence: Level I, Prospective randomed comparative study.

1. Introduction

Total knee arthroplasty (TKA) has been proven to be an efficient surgical treatment of knee joint disorders because of excellent survival rates and long-term results, but patients' satisfaction after TKA is still ≤70–75% [27,28,33]. The range of motion is one important factor affecting a patient's satisfaction with the outcome of TKA, especially in Asian countries; cultural factors cause patients in Asia to frequently perform activities involving strong knee flexion such as squatting, kneeling or sitting cross-legged [26,30]. Patients' functional abilities seem strongly linked to successful restoration of normal motion in the replaced joint [2,3,23,32,40]. To perform deep knee bending after TKA, a bicondylar roll-back motion pattern such as that in a healthy knee is desirable [17,25]. Posterior translation of the femoral condyle and internal rotation of the tibia appear to be two important factors related to good knee flexion [3]. Nevertheless, in vivo fluoroscopic analyses of various types of prostheses for total knee arthroplasty have shown numerous kinematic abnormalities: paradoxical anterior–femoral translation, reverse axial rotational patterns and abnormal femoral condylar lift-off are commonly present [5,9,35]. Although some studies reported kinematics after TKA procedures that is similar to that of a healthy knee, posterior roll-back of the femoral condyle and tibial axial rotation are still much worse than those in a healthy knee [31]. How to improve the femoral condylar roll-back and tibial internal rotation during knee flexion is still a challenging question for surgeons and prosthesis manufacturers.

More recently, a novel rotationally unconstrained and fixed-bearing posterior-stabilised prosthesis for TKA, Scorpio Non-Restrictive Geometry (NRG) implant (Stryker Orthopedics, Mahwah, NJ) came on the market. This prosthesis is a recent product incorporating various modifications of the previous Scorpio Knee System (Stryker Orthopedics) and is advertised as a system improving the femoral condyle translation in the sagittal plane and reducing the restriction of tibial axial rotation in the transverse plane (Figs. 1 and 2). Although several studies have reported that an NRG implant improves TKA kinematics [4,39], no study to date has compared kinematics after the contemporary NRG

* Corresponding author.
E-mail address: peifuxing@yeah.net (F. Pei).

http://dx.doi.org/10.1016/j.knee.2014.10.013
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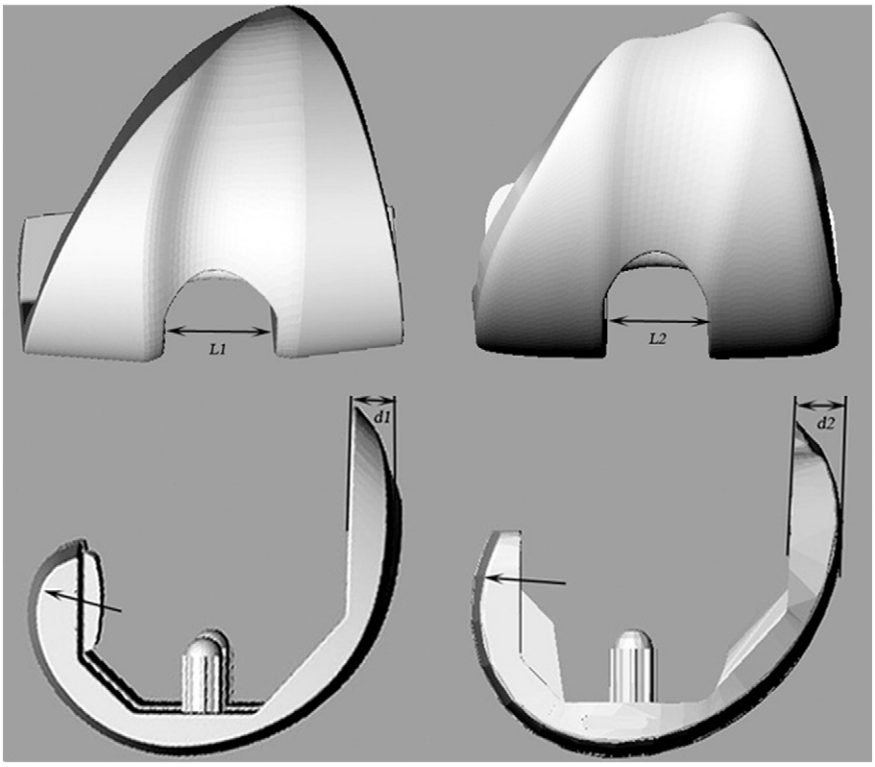

Fig. 1. A projection drawing showing the difference between the non-restrictive geometry (NRG; left) and ScorpioFlex (right) femoral components in their frontal (top) and sagittal (bottom) views; both exhibit medial–lateral symmetry in the condyles and are used in single-radius TKA. The anterior flange of the NRG design was reduced by 2 mm ($d2 - d1 = 2$) to decrease stress on the extensor mechanism, retinaculum and widened intercondylar notch ($L1 > L2$). Meanwhile, the NRG implant shows a much smaller deep-flexion radius from 95° to 155° compared to the ScorpioFlex implant (black arrow) and thereby ensures a relatively relaxed arrangement of the posterior structure.

TKA (has features designed to promote good flexion) with kinematics after the conventional ScorpioFlex TKA in patients with bilateral TKA of these two types.

The goal of this study was to compare kinematics under weight-bearing deep knee-bending motion in patients with bilateral TKA of two types: 1) involving a conventional ScorpioFlex prosthesis and 2) based on the contemporary redesigned NRG prosthesis installed by the same surgeon. We hypothesised that the knee that receives the NRG prosthesis would show better posterior roll-back and axial rotation than would the ScorpioFlex implant.

2. Materials and methods

Prior to the study, the Institutional Review Board of West China Hospital of Sichuan University approved the study protocol, and written informed consent was obtained from the patients. We enrolled the

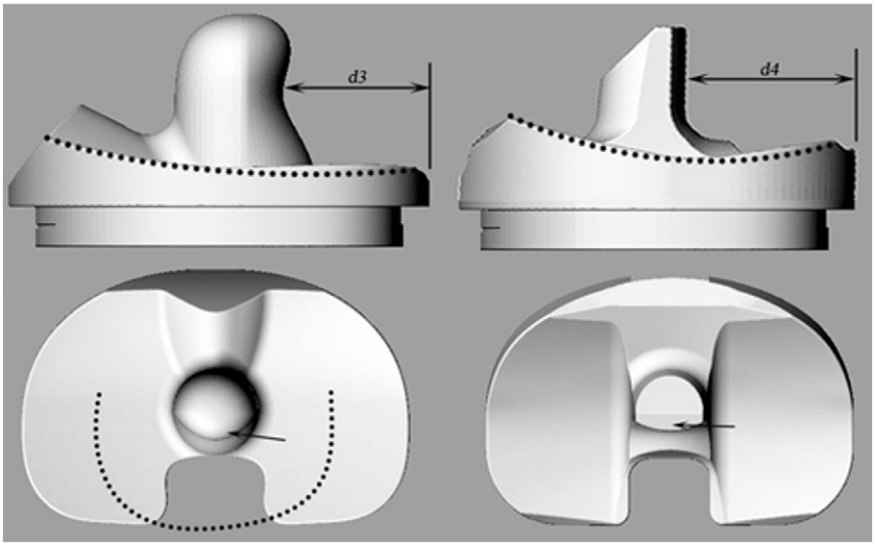

Fig. 2. A projection drawing showing the difference between the non-restrictive geometry (NRG; left) and ScorpioFlex (right) polyethylene insert in their sagittal (above) and transverse (below) views. In the sagittal view, the post of the NRG implant is much closer to the posterior edge of the insert compared to the ScorpioFlex implant ($d3 < d4$); the NRG has a lower posterior lip (dashed line). In the transverse view, the spherical arc articulating surface (dashed line) and the round post (black arrow) are the most characteristic differences between the two designs.