The Journal of Arthroplasty 29 (2014) 2407–2411

Contents lists available at ScienceDirect

The Journal of Arthroplasty

journal homepage: www.arthroplastyjournal.org

In Vivo Movement of Femoral Flexion Axis of a Single-Radius Total Knee Arthroplasty

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ARTICLE INFO

Article history:
Received 31 July 2013
Accepted 1 December 2013

Keywords:
single-radius TKA
posterior stabilized
kinematics
paradoxical movement
femoral roll back

ABSTRACT

The objective of this study was to investigate in vivo femoro-tibial motion using the movement of femoral flexion axis of a single-radius TKA. We examined 20 clinically successful knees with a single-radius posterior stabilized TKA to evaluate the kinematics of deep knee flexion using 2–3-dimensional registration techniques. The mean knee flexion range of motion was 117.8°. The mean rotation of the femoral component was 7.6° external rotation. The mean knee flexion angle at initial post-cam engagement was 55.2°. No paradoxical movement of femoral component was shown until 70° flexion, afterward the femoral component rolled back with flexion. The data showed that the design of this prosthesis might contribute to reduce the paradoxical anterior femoral movement and provide stability in mid-flexion ranges.

Total knee arthroplasty (TKA) is a highly effective procedure that provides reliable relief from pain, improved physical function, and a high level of patient satisfaction in patients with advanced knee osteoarthritis [1,2]. However, there are still several problems to be elucidated and improved. A high percentage of arthroplasty patients describe significant limitations in function compared to age- and gender-matched group [3]. Some patients describe symptoms of instability, with recurrent effusions and demonstrate tenderness on physical examination [4–6]. To reduce these complaints, new designs of TKA that aim to restore normal kinematics of the knee has been developed.

Numerous factors play a role in determining postoperative in vivo knee kinematics and can be categorized into the implant design, the alignment of implants to the bone, changes in the joint line, soft tissue balance and tension, and retention or sacrifice of the posterior cruciate ligament (PCL) [7–10]. We have reported that the implant design considerably affect knee kinematics in weight-bearing deep knee flexion, using same analytical methodology [11–17]. Considering implant design, the different radius of femoral component and the geometry of the tibial polyethylene insert might affect knee kinematics.

Single-radius femoral component design was introduced in 1996 in an attempt to more accurately reproduce the kinematics of the natural knee [18]. The design is based on the premise that for the knee functional flexion-extension axis, there is only one average axis location. This flexion axis is fixed to the femur and, therefore, during knee internal/external rotation, also rotates with the femur [18–20]. Previous biomechanical studies have shown that after stabilization of flexion/extension axis, the paradoxical anterior femoral movement is reduced and the quadriceps lever arm is improved [21–24].

Controversy as to how the femur moves on the tibia during flexion is still ongoing [25–27]. The movement of femoro-tibial contact point is probably the most widely evaluated. However, there was a discrepancy between the movement of contact points and of the condyles themselves [27]. In regard to single-radius TKA, the flexion axis that is fixed to femoral component could be computed. If the movement of femoral flexion axis relative to tibia represents the femoro-tibial motion, the precise evaluation of femoral movement, the pivot pattern, and the rollback would be available.

With the sacrifice of the cruciate ligaments in the conventional knee implant, paradoxical anterior femoral movement with increasing flexion can sometimes be present [28]. The use of a single-radius TKA has been proposed to ensure consistent tension in the collateral ligaments throughout the functional range of movement. We hypothesized that a single femoral radius design TKA would offer a potential minimization of the paradoxical movement and provide joint stability, as the flexion-extension axis is kinematically stabilized. The objective of this study was to evaluate the in vivo femoro-tibial kinematics during deep knee flexion using the movement of femoral flexion axis of a single-radius TKA.

Patients and Methods

We analyzed 20 knees (16 patients, 1 male and 15 female) who underwent successful TKA resulting in a Knee Society Score higher than 90 and who agreed to participate in the current investigation

The Conflict of Interest statement associated with this article can be found at http://dx.doi.org/10.1016/j.arth.2013.12.001.

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http://dx.doi.org/10.1016/j.arth.2013.12.001
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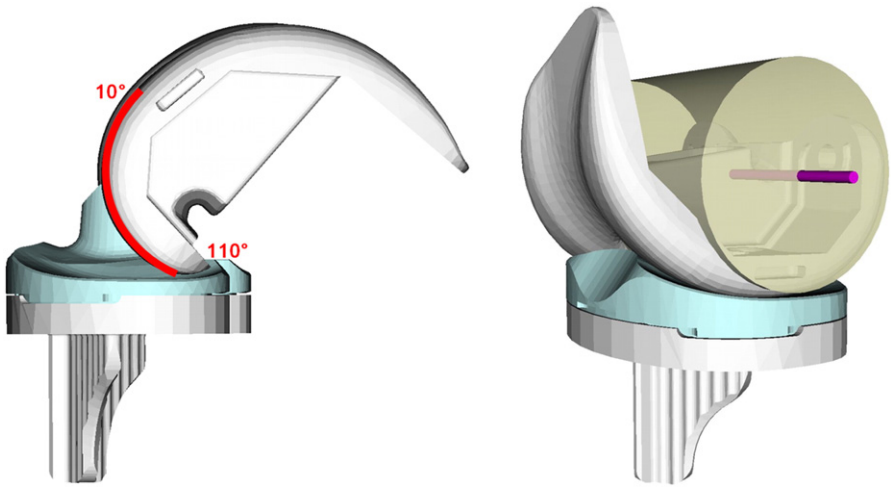

Fig. 1. Triathlon PS TKA (Stryker Orthopedics, Mahwah, NJ). The femoral component has a single anterior/posterior radius from 10° to 110° flexion. The flexion axis was identified by the center of the femoral circular surface.

under institutional review board approval. All patients were implanted with a Posterior Stabilized TKA (Triathlon PS, Stryker Orthopedics, Mahwah, NJ) (Fig. 1) between 2008 and 2010. One senior author performed all of the TKA procedures using minimally invasive techniques. The joint gaps in flexion and extension were equalized. Thirteen patients had osteoarthritis and three patients had

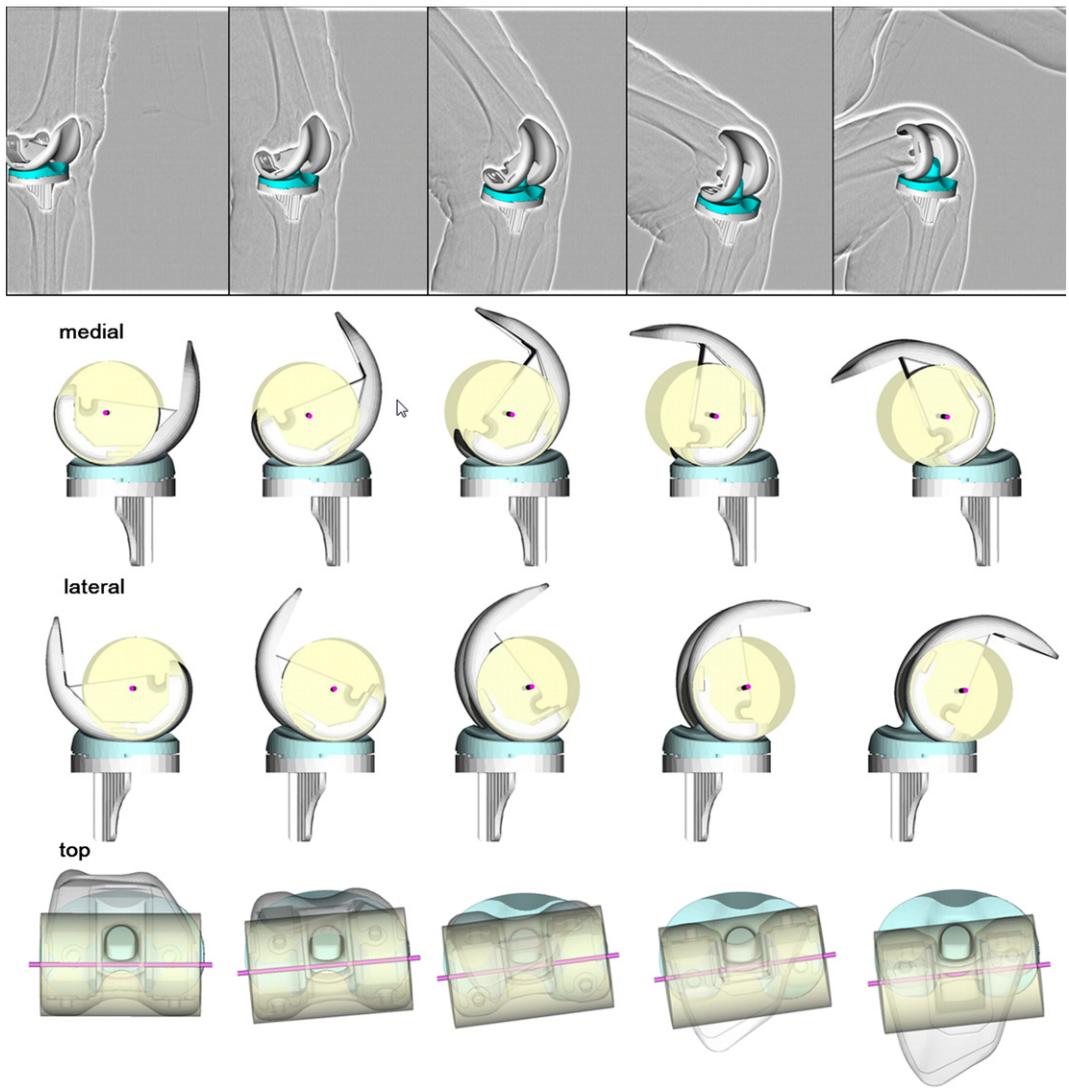

Fig. 2. The motion from full extension to maximum flexion was performed under weight-bearing condition. The femoral flexion axis moved more posteriorly on lateral side than medial side with flexion.