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Intra-operative joint gap kinematics in unicompartmental knee arthroplasty

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ABSTRACT

Background: The use of an offset type tensor for total knee arthroplasty that can be set with patellofemoral joint reduction and femoral component placement enables surgeons to assess soft tissues in the physiological postoperative knee condition, showing different kinematic pattern of soft tissues in varus osteoarthritic knees between cruciate-retaining and posterior-stabilized total knee arthroplasty. However, gap kinematics in unicompartmental knee arthroplasty is unclear.

Methods: Using a newly developed tensor that is designed to assess soft tissue balance throughout the full range of motion with femoral component placement, we assessed the intra-operative joint gap measurements of unicompartmental knee arthroplasties performed at 0, 10, 30, 45, 60, 90, 120 and 135° of flexion in 20 osteoarthritic patients. In addition, the kinematic pattern of unicompartmental knee arthroplasty was compared with those of cruciate-retaining and posterior-stabilized total knee arthroplasty that were calculated as medial compartment gap from the previous series of this study.

Findings: While the joint gap measurements of unicompartmental knee arthroplasties increased from full extension to extension (10° of flexion), these values remained constant throughout the full range of motion. Of note, the gap values of cruciate-retaining total knee arthroplasty were significantly smaller from midrange to deep flexion compared with posterior-stabilized total knee arthroplasty, and furthermore unicompartmental knee arthroplasty showed a significantly smaller gap from extension to midrange flexion compared with cruciate-retaining total knee arthroplasty.

Interpretation: Accordingly, we conclude that the intra-operative joint gap kinematic pattern in unicompartmental knee arthroplasty differs from the pattern in total knee arthroplasty.

1. Introduction

One of the primary goals of total knee arthroplasty (TKA) is to achieve stable tibiofemoral and patellofemoral (PF) joints, which relies on accurately aligning these joint components and balancing the soft tissues (Dorr and Boiardo, 1986; Insall et al., 1979, 1985). Although recent advances in technology and devices to assist surgery such as navigation systems or patient specific instrumentations provide achievement of appropriate osteotomies and implantations (Dossett et al., 2012; Lutzner et al., 2008; Mizu-uchi et al., 2008; Nunley et al., 2012; Sparmann et al., 2003; Stulberg et al., 2002), intra-operative management of soft tissues is still difficult and challenging. Up to now, using an offset type tensor that enables surgeons to assess and balance soft tissues in the physiological postoperative knee condition with PF joint reduction and femoral component placement (Matsumoto et al., 2006; Muratsu et al., 2010), the kinematic pattern of soft tissues in varus osteoarthritic knees has been reported in cruciate-retaining (CR) TKA as well as posterior-stabilized (PS) TKA (Matsumoto et al., 2009, 2011b). In one study series, the joint component gap and ligament balance were different between CR and PS TKA, which was considered a result of the existence of the posterior cruciate ligament (PCL) (Matsumoto et al., 2009, 2011b).

Although unicompartmental knee arthroplasty (UKA) is well known to have advantages over conventional TKA such as acquisition of range of motion and kinematics (Akizuki et al., 2009; Dalury et al., 2009; Laurencin et al., 1991), the reason for these advantages has not been fully investigated. We hypothesized that the kinematic soft tissue pattern in UKA alone with the existence of the cruciate ligament accounts for the difference between UKA and TKA. In the present study, accordingly, we report our experience with a newly developed tensor device for intra-operative joint gap measurements of UKA, performed with the femoral component in place. The first purpose of the present study is to assess joint gap kinematics in UKA. Secondly, we attempted to compare the pattern in UKA with those in CR and PS TKA with the reduced PF joint and femoral component placement, which more closely reproduces postoperative joint alignment.

2. Methods

UKA was undertaken in patients with substantial pain and loss of function meeting the following criteria: isolated medial compartmental

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osteoarthritis or idiopathic necrosis; fixed flexion deformity of less than 5°; an active range of motion (ROM) of greater than 90°; and less than 15° of varus deformity. Between 2010 and 2011, according to the above criteria, 20 patients (17 women and 3 men) with a mean age of 72.8 (SD 1.6) years were selected to receive medial Zimmer Unicompartmental High Flex Knee System (Zimmer Inc, Warsaw, Ind). The average preoperative coronal plane alignment was 6.4° (SD 0.8°) in varus. Each surgery was performed by the two senior authors who each have more than 10 years of experience performing knee arthroplasty.

In order to make a fair assessment and minimize the influences of clinical variables, age-matched patients receiving 20 CR TKAs (NexGen CR Flex, Zimmer, Inc., Warsaw, IN) and 20 PS TKAs (NexGen LPS Flex, Zimmer, Inc., Warsaw, IN) previously performed at the same institution and by the same surgeons were retrospectively selected for the comparison of gap kinematics. The patient population comprised CR TKA with a mean age of 74.6 (SD 1.4) years, and PS TKA with a mean age of 74.2 (SD 1.4) years. Average preoperative coronal plane alignments were 9.7° (SD 1.9°) in varus in CR TKA and 9.7° (SD 2.0°) in varus in PS TKA. Surgical procedure was previously described (Matsumoto et al., 2009, 2011b). Briefly, all TKAs were performed using the measured resection technique with a conventional resection block and spacer block. A distal femoral osteotomy perpendicular to the mechanical axis of the femur was performed using preoperative long leg radiographs. Femoral external rotation was preset at 3, 5, or 7° relative to the posterior condylar axis according to the preoperative computer tomography and epicondylar view radiograph. A proximal tibial osteotomy was performed ensuring that each cut was made perpendicular to the mechanical axis in the coronal plane and with 7° of posterior inclination along the sagittal plane. Following each bony resection and necessary soft tissue release, the tensor was fixed to the proximal tibia and fitted to the femoral trial prosthesis. The joint distraction force was set at 40 lb. in all patients receiving TKAs. The measurement of joint component gap (center gap) and ligament balance (varus angle) was performed at 0, 10, 30, 45, 60, 90, 120, 135° of flexion using an offset type tensor with the PF joint reduction and femoral component placement.

2.1. UKA tensor

UKA tensor was developed with the basic concept of an offset type tensor and the design and initial measurements have been previously reported (Matsumoto et al., 2006, 2009, 2011b; Muratsu et al., 2010). The UKA tensor consists of three parts: an upper seesaw plate, a lower platform plate with a spike and an extra-articular main body (Fig. 1A). Both plates are placed at the medial compartment of the knee (Fig. 1B). This device is ultimately designed to permit surgeons to measure the joint medial compartment/joint component gap, while applying a constant joint distraction force. Joint distraction forces ranging from 10 lb (4.5 kg) to 40 lb (18.2 kg) can be exerted between the seesaw and platform plates through a specially made torque driver which can change the applied torque value (Fig. 1C). After sterilization, this torque driver is placed on a rack that contains a pinion mechanism along the extra-articular main body, and the appropriate torque is applied to generate the designated distraction force; in preliminary in-vitro experiments, we obtained an error for joint distraction within 3%. Once appropriately distracted, attention is focused on the distance (mm) between the center midpoints of upper surface of the seesaw plate and the proximal tibial cut. By measuring the distance under a constant joint distraction force, joint medial compartment/joint component gaps can be measured.

2.2. Intra-operative measurement

All UKA were performed with a conventional resection block and spacer block according to the instructions. After inflating the air tourniquet with 280 mmHg at the outset of each procedure, a limited medial parapatellar approach with an incision from the superomedial border of the patellar to 1.5 cm distal to the medial tibial plateau articular surface was performed. The patella was subluxated for exposure and the ACL and the patellofemoral and lateral compartments were inspected to ensure a UKA was a suitable intervention. Following a minimum soft tissue release of medial structures and the necessary removal of osteophytes, a proximal tibial osteotomy was performed first ensuring that each cut was made perpendicular to the mechanical axis in the coronal plane and with 7° of posterior inclination along the sagittal plane. Next, a distal femoral osteotomy was performed perpendicular to the mechanical axis of the femur adjusting the surface of the proximal tibial cut. Femoral rotation was carefully adjusted to mechanical axis of the tibia and femur and the remaining osteotomies of the femur were performed.

Following each bony resection and necessary soft tissue release, the tensor was fixed to the proximal tibia and fitted to the femoral trial prosthesis. The joint distraction force was set at 20 lb. in all patients. We selected this distraction force to reflect the force of 40 lb. applied in TKA, in which the force of 20 lb. is to be divided into each lateral/medial compartment. This joint distraction force was loaded several times until the joint component gap remained constant; this was done to reduce the error which can result from creep elongation of the surrounding soft tissues. At this point, the joint

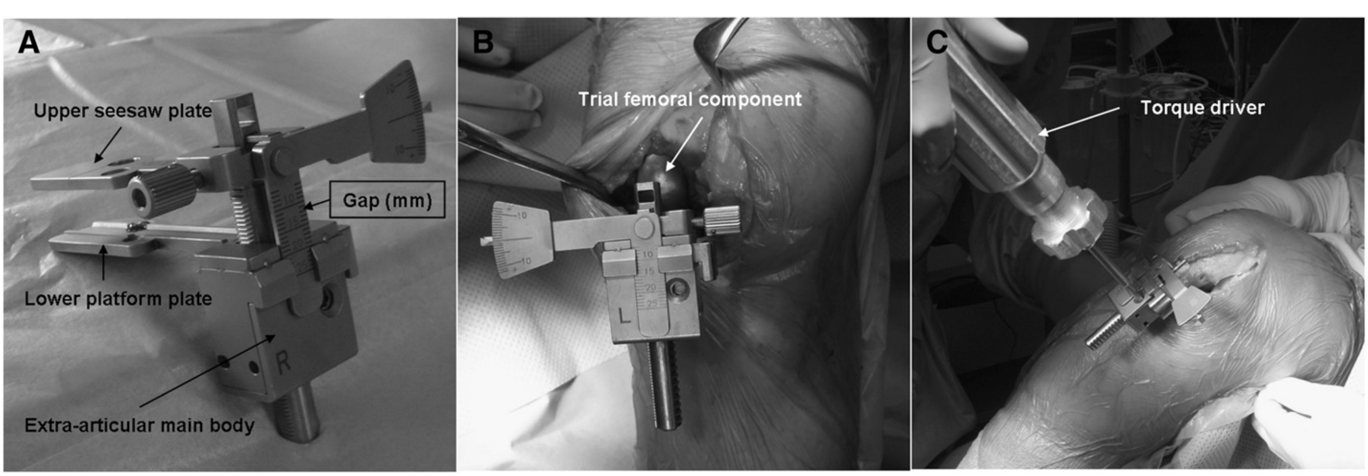

Fig. 1. UKA tensor. (A) The new tensor consists of three parts: upper seesaw plate, lower platform plate and extra-articular main body. (B) Two plates are connected to the extra-articular main body by the connection arm through a limited medial parapatellar arthrotomy. (C) Joint distraction forces can be exerted between the seesaw and platform plates through a specially made torque driver which can change the applied torque value.