Clinical Biomechanics 30 (2015) 95–99

Contents lists available at ScienceDirect

Clinical Biomechanics

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

Joint gap assessment with a tensor is useful for the selection of insert thickness in unicompartmental knee arthroplasty

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ARTICLE INFO

Article history:
Received 4 April 2014
Accepted 27 October 2014

Keywords:
Unicompartmental knee arthroplasty
Tensor
Component gap
Insert selection
Kinematics

ABSTRACT

Background: The success of unicompartmental knee arthroplasty relies on a lot of factors such as correct osteotomy and proper soft-tissue tensioning. A selection of insert thickness depends solely on the surgeon's subjective feeling. Recently, a tensor that is designed to assess soft tissue balance during unicompartmental knee arthroplasty has been developed. The purpose of this study was to compare the component gap throughout the range of motion among different distraction forces and examine the correlation between the component gap and the insert thickness.

Methods: 30 cases of 29 patients were included. All the patients received a conventional medial Zimmer Unicompartmental High Flex Knee System. Using a tensor under 10, 20, 30, and 40 lb distraction forces, after femoral component placement, the component gaps were assessed throughout the range of motion. The correlations between the component gap and the insert thickness selected were examined.

Findings: The component gap showed the same kinematic pattern among the different distraction forces and the value increased in proportion to the increase of the distraction force in unicompartmental knee arthroplasty. The insert thickness in unicompartmental knee arthroplasty was found to have a strong positive correlation with the component gap from 10 to 45° of knee flexion with a distraction force of more than 20 lb

Interpretation: With the use of the tensor, surgeons can quantify the component gap and objectify their insert thickness decision compared with the use of tension gauge.

1. Introduction

In the last 10 years, there has been an increase in the survivorship of unicompartmental knee arthroplasty (UKA) because of the numerous advances in UKA instrumentation and cement fixation techniques (Labek et al., 2011; Lombardi et al., 2012). Recent studies have demonstrated that UKA yields a better clinical outcome compared to total knee arthroplasty (TKA), with benefits such as reduced blood loss, reduced perioperative morbidity, shorter rehabilitation, and increased postoperative range of motion (ROM) (Akizuki et al., 2009; Amin et al., 2006; Dalury et al., 2009; Laurencin et al., 1991).

The accumulated evidence indicates that the use of an offset-type tensor for TKA with a reduced patellofemoral (PF) joint and femoral component in place provided surgeons with an accurate assessment tool when performing TKA, while preserving certain physiological conditions of the knee; moreover, it provides the insight needed for the acquisition of an appropriate soft tissue balance (Gejo et al., 2008, 2010; Matsumoto et al., 2006, 2011; Muratsu et al., 2010). By contrast, the quantitative measurement or evaluation index of achieving soft tissue tensioning during UKA has yet to be elucidated. There was no objective evaluation method to detect tightness or looseness of component gap. A selection of insert thickness depends solely on the surgeon's subjective feeling, referring to the flexion/extension gap spacer with 2 mm end of the tension gauge to ensure that flexion and extension gaps are not too tight. Failures in UKA have mainly been attributed to improper component alignment that may lead to altered knee biomechanics along with accelerated polyethylene wear if the deformity is undercorrected and in disease progression of other compartments if the deformity is overcorrected (Collier et al., 2006; Conditt and Roche, 2009; Hernigou and Deschamps, 2004; Lonner, 2009; Ridgeway et al., 2002). In addition to accurate joint alignment, the success of UKA relies on appropriate soft-tissue tensioning to obtain a balanced extension–flexion gap and varus–valgus stability (Whiteside, 2005). An objective selection criterion of insert thickness is needed, because subjective

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http://dx.doi.org/10.1016/j.clinbiomech.2014.10.008
0268-0033/

selection of insert thickness might cause mismatches between intersurgeons and intrasurgeons. A quantitative information about soft tissue tensioning in UKA could assist surgeons to realize component gap values and to select proper insert thickness.

Recently, a tensor was developed that is designed to assess soft tissue tensioning during UKA (Matsumoto et al., 2013). This tensor enables surgeons to assess the intra-operative joint gap after femoral component placement, also known as the "component gap," throughout the ROM under various distraction forces. To measure component gaps during UKA might be able to reduce mismatches of insert thickness selection between intersurgeons and intrasurgeons and will be able to make some selection criteria of insert thickness. However, it has not been clear how the component gap kinematics are influenced by the different distraction forces and which distraction force is correlated with the insert thickness. The primary purpose of this study is to examine the component gap throughout the ROM among different distraction forces in UKA. Furthermore, the correlation between the component gap and the insert thickness was examined to explore the appropriate selection of insert thickness.

2. Methods

The study was approved by the institutional review board, and informed consent was obtained from all patients. A surgical criteria for UKA were a radiographic diagnosis of isolated medial compartmental osteoarthritis or idiopathic osteonecrosis with fixed flexion deformity of <5°, an active ROM over 90°, and a varus deformity of <15°. Between November 2010 and November 2012, a total of 30 knees in 29 patients were selected to receive medial Zimmer Unicompartmental High Flex Knee System (Zimmer Inc., Warsaw, USA). The mean age of the patients at time of operation was 70.6 years (range, 54–82; SD: 8.0). There were 10 male patients (10 knees) and 19 female patients (20 knees). There were 17 osteoarthritis knee and 13 idiopathic osteonecrosis knees. The mean follow up was 30.6 months (range, 15–39; SD: 6.4 months). The preoperative mean hip–knee–ankle angle (HKA) angle was 6.7 degree varus (range, 12 degree varus–1 degree varus; SD: 3.2), mean knee flexion angle was 127.2° (range, 110–140; SD: 10.0), mean Knee Society Knee Score was 47.4 (range, 39–60; SD: 6.5), and mean Function Score was 47.5 (range, 30–64; SD: 8.7) (Table 1).

2.1. UKA tensor

Reports on the design and the methodology of the UKA tensor have previously been published (Matsumoto et al., 2013). The UKA tensor consists of 3 parts, namely an upper plate, a lower platform plate with a spike, and an extra-articular main body (Fig. 1A). Both plates are to be placed at the medial compartment of the knee (Fig. 1B). This device is designed to permit surgeons to measure the 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 upper and lower plates through a specially made torque driver that 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. Torque is subsequently applied to generate 10, 20, 30, and 40 lb distraction forces in this order. In preliminary in-vitro experiments, an error for joint distraction within ±3% was obtained. After each distraction force was applied, the component gap (in mm) between the center midpoints of the upper surface of the plate and the proximal tibial cut was measured.

Table 1
Patient demographics.

Age at surgery (years)		70.6 (SD: 8.0)
Sex (male/female)		10 knees/20 knees
Diagnosis (OA/ON)		17 knees/13 knees
Preop	HKA	6.7 degree varus (SD: 3.2)
	Extension	−4.7° (SD: 3.7)
	Flexion	127.2° (SD: 10.0)
	KS knee score	47.4 (SD: 6.5)
	KS function score	47.5 (SD: 8.7)
Postop	HKA	0.8 degree varus (SD: 2.4)
	Posterior slope of tibial osteotomy	6.7° (SD: 2.2)
	Coronal alignment of tibial osteotomy	2.6 degree varus (SD: 2.1)
	Extension	−0.5° (SD: 1.5)
	Flexion	130.5° (SD: 8.6)
	KS knee score	92.4 (SD: 4.4)
	KS function score	92.2 (SD: 7.1)

OA: Osteoarthritis, ON: Osteonecrosis, HKA: Hip–knee–ankle angle, KS: Knee Society.

2.2. Intraoperative measurement

All UKA was performed by 2 senior authors (T.M. and H.M.) who have more than 10 years of experience in performing knee arthroplasty. After inflating the tourniquet to 280 mm Hg, a limited medial parapatellar approach was employed with an incision from the superomedial border of the patella to 1.5 cm distal to the medial tibia plateau articular surface. Following exposure of the anterior cruciate ligament (ACL) and inspection of the patellofemoral and lateral compartments, minimal soft tissue release of the medial structures and osteophyte removal was performed. A proximal tibial osteotomy was then performed using an extramedullary (EM) alignment guide after ensuring that the bone cut was made perpendicular to the mechanical axis in the coronal plane and with from 3 to 10° of posterior inclination along the sagittal plane of the tibia, with reference to an individual anatomical tibial slope. Following the tibial osteotomy, a distal femoral osteotomy was performed perpendicular to the mechanical axis of the femur, while referring to the surface of the proximal tibial cut. Femoral rotation was adjusted to the mechanical axis of the tibia, and the remaining osteotomies of the femur were performed.

Following the femoral bony resection and with the femoral trial prosthesis in place, the tensor was fitted with its lower platform fixed to the proximal tibia and the upper plate fitted to the medial femoral component. During the measurement, the medial parapatellar arthrotomy was temporarily repaired by applying stitches proximally to the connection arm of the tensor. The thigh and knee were aligned in the sagittal plane to eliminate the external load on the knee. The joint distraction forces were pre-loaded several times until the joint gap remained constant in order to reduce the error that may result from creep elongation in the surrounding soft tissue. The joint gap (measured in mm), defined as the component gap between the medial tibial osteotomy surface and the femoral trial prosthesis was measured by one of another author (K.T.). The surgeons were blinded to the results of the component gaps. The component gap was measured at 0 (full extension); 10 (extension); 30, 45, and 60 (mid-range of flexion); 90 (flexion); and 120 and 135 (deep flexion) degrees of knee flexion with distraction forces of 10, 20, 30, and 40 lb in this order. In this study, the insert thickness was selected referring to the flexion/extension gap using the 2 mm end of the tension gauge to ensure that flexion and extension gaps are not too tight, also according to the surgical technique procedure of the manufacturer.

2.3. Statistical considerations

2.3.1. Analysis

Inter-observer and intra-observer variability was assessed for the joint gap measurement using a subset of 10 cases. The mean absolute value of the difference between 2 repeated measurements was 0.1 mm (95% confidence interval (95% CI) −0.1 to 0.3 mm). The mean absolute value of the difference between the 2 observers was 0.2 mm (95% CI −0.1 to 0.5 mm). The data are expressed as a mean ± standard error of the mean (SE). For the purpose of comparing the parameters in the component gap between each angle, repeated measured ANOVA was applied and multiple pair-wise comparisons were performed