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Original Article

Contact Kinematic Differences Between Gap Balanced vs Measured Resection Techniques for Single Radius Posterior-Stabilized Total Knee Arthroplasty

Matthew G. Teeter, PhD [a, b, c, d, *], Kevin I. Perry, MD, MSc [a, e], Xunhua Yuan, PhD [d], James L. Howard, MD, MSc, FRCSC [a], Brent A. Lanting, MD, MSc, FRCSC [a]

[a] Division of Orthopaedic Surgery, Department of Surgery, Schulich School of Medicine & Dentistry, Western University and London Health Sciences Centre, London, ON, Canada
[b] Department of Medical Biophysics, Schulich School of Medicine & Dentistry, Western University, London, ON, Canada
[c] Surgical Innovation Program, Lawson Health Research Institute, London, ON, Canada
[d] Imaging Research Laboratories, Robarts Research Institute, London, ON, Canada
[e] Department of Orthopaedic Surgery, Mayo Clinic, Rochester, Minnesota

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ABSTRACT

Background: Measured resection (MR) and gap balancing (GB) are common surgical techniques for total knee arthroplasty (TKA). Controversy has arisen as each conceptually differs in how the knee is balanced through bone and soft tissue management. The objective of the present study was to compare both the frequency of condylar liftoff and the location of femorotibial contact from extension through midflexion between patients undergoing GB or MR TKA.

Methods: A total of 24 knees (23 patients) were randomly assigned at referral to either a surgeon performing MR or GB TKA with the same single radius, posterior-stabilized implant (12 per cohort). At 1-year postoperation, patients underwent biplanar radiographic imaging at 0°, 20°, 40°, and 60° of flexion. Condylar liftoff, contact location, and magnitude of excursion on each condyle were measured. Preoperative and postoperative clinical outcome scores were also collected.

Results: There was no difference ($P = .41$) in the frequency of liftoff between cohorts. The MR cohort had more posterior contact on the medial condyle ($P < .01$) and more anterior contact on the lateral condyle ($P < .01$) throughout flexion. Motion patterns were similar between cohorts, with similar medial ($P = .48$) and lateral ($P = .44$) excursion, which was equal in magnitude between condyles for both MR ($P = .48$) and GB ($P = .73$). There was no difference in clinical outcome scores between groups.

Conclusion: For this particular implant system, GB and MR appear to produce similar kinematic and patient-reported outcome results.

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Total knee arthroplasty (TKA) is a popular procedure with excellent outcomes for most patients. Nevertheless, dissatisfaction remains for up to 1 in 5 patients [1], leading surgeons to seek improvements in TKA surgical technique, especially surrounding implant alignment, balance of the knee, and the treatment of soft tissues [2]. A common debate between surgeons is the use of a gap balancing (GB) or measured resection (MR) technique. In GB, rectangular joint spaces equal in magnitude are created in flexion and extension, enabled by an appropriate rotation of the femoral bone cuts. In MR, bony resections are performed first to match anatomical landmarks, and soft tissue releases are subsequently performed to balance the joint space. Proponents of GB suggest that their technique offers greater coronal plane stability with improved femoral component rotation leading to equal and balanced flexion and/or extension gaps [3,4]. However, disadvantages of GB include potential for an elevated joint line and greater variability in femoral component rotation [5]. Proponents of the MR technique

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* Reprint requests: Matthew G Teeter, PhD, 339 Windermere Road, London, ON N6A 5A5, Canada.
E-mail address: matthew.teeter@lhsc.on.ca (M.G. Teeter).

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emphasize that the natural knee anatomy (including the joint line) is maintained, and that using anatomical landmarks offer greater accuracy [6]. However, the precision of determining the location of these landmarks can be challenging, and soft tissue releases may be required to achieve an appropriate flexion and/or extension gap [7,8]. Regardless of these factors, clinical outcomes have not shown a difference between GB and MR TKA [5,9].

Fluoroscopic studies have been used to examine condylar liftoff and kinematics between patients receiving MR and GB TKA, and within various versions of GB TKA. It is postulated that liftoff is a manifestation of coronal instability or malrotation of the femoral component [3,10]. This liftoff might then lead to eccentric loading, premature wear, and component loosening [10,11]. Dennis et al [3] found significantly greater rates of condylar liftoff with MR than GB, and within the MR group, greater rates of liftoff with cruciate-retaining TKA than posterior-stabilized TKA. Suzuki et al [12] found greater posterior motion of the lateral condyle relative to the medial condyle in weight-bearing and non–weight-bearing flexion of a posterior-stabilized TKA performed using GB in valgus knees, which was similar in pattern to the same procedure performed in varus knees. Fitz et al [13] compared 2 versions of GB cruciate-retaining TKA and found greater lateral liftoff with the traditional technique vs their new technique that included a more anatomical reconstruction of the medial condylar J curve. They also found greater lateral condylar rollback with the new technique. Baier et al [14] used intraoperative navigation to compare liftoff and kinematics between navigated MR and modified GB cruciate-retaining TKA. They found no liftoff in the MR group, but consistent lateral liftoff of >1 mm on average in the GB group from 10°-120°. Both groups had greater lateral condylar rollback than medial, and the magnitude was greater in the GB group.

The objective of the present study was to compare both the frequency of condylar liftoff and the location of femorotibial contact from extension through midflexion between patients undergoing GB or MR TKA using a single radius, posterior-stabilized design. Clinical outcomes between the 2 cohorts were also examined.

Methods

Twenty-three patients (24 knees) were recruited for the study by random assignment on referral to either a surgeon performing a GB technique or an MR technique. The primary inclusion criterion was osteoarthritis of the knee requiring primary TKA. Exclusion criteria included prior knee surgery, if the patient was pregnant or trying to become pregnant, cognitive impairment, a history of alcoholism, or if the patient was to undergo bilateral, simultaneous TKA. Our institutional ethics review board reviewed and approved the study.

Twelve knees were assigned per GB and MR cohort. Patient demographics are listed in Table 1. There was no significant difference in age, sex, height, or side between the cohorts; however, patients in the GB group were significantly heavier ($P = .04$) and had a significantly greater body mass index ($P = .002$).

Patients in both cohorts underwent TKA surgery by a fellowship-trained arthroplasty surgeon and received identical fixed-bearing, posterior-stabilized TKA (Triathlon, Stryker, Mahwah, NJ) with cemented fixation. The Triathlon femoral component has a single radius of curvature in the sagittal plane from 10° to 110° of flexion. The posterior condyles are short and flared to enable deep flexion up to 150°, with up to 20° of internal and/or external rotation. For both groups, a standard midline incision was made and a medial parapatellar arthrotomy was performed. In the MR cohort, the femoral component rotation was set at 3° of external rotation relative to the posterior condylar axis. After making bone cuts based on anatomic landmarks, judicious soft tissue releases were conducted to create a balanced knee in flexion and extension. Eight patients received a 50% release of the deep medial collateral ligament to the midcoronal plane, and 4 patients received a complete release of the deep medial collateral ligament, with 2 of these latter patients also receiving a release of the medial posterior joint capsule. In the GB cohort, the distal femur and proximal tibial resection were performed based on anatomic landmarks and preoperative templating, and the medial and lateral gaps were balanced first with the knee in extension using spacer blocks. Ten patients received a 50% release of the deep medial collateral ligament to the midcoronal plane, and 2 patients received releases of the entire deep medial collateral ligament, the medial posterior joint capsule, semimembranosus, the posterior oblique ligament, and had a tibial reduction osteotomy. After achieving a balanced extension space, femoral component rotation was set based on the tibial resection using a central pivoting McBride tensioner (Fig. 1) to create symmetric flexion and extension spaces of equal magnitude. The anterior-posterior translation was set to create equivalent flexion and extension gaps.

Table 1
Patient Demographics (Mean ± Standard Deviation).

	Measured Resection	Gap Balancing	*P* Value
Age, y	70.0 ± 7.9	67.2 ± 7.0	.37
Height, cm	172.2 ± 7.1	166.5 ± 11.3	.18
Weight, kg	82.7 ± 16.7	102.3 ± 24.3	.04
BMI, kg/m^2	27.8 ± 4.7	36.7 ± 6.6	.002
Sex	7 males, 5 females	3 males, 8 females	.21
Side	8 right, 4 left	7 right, 5 left	1.00
Preoperative hip-knee-ankle angle, °	7.7 ± 4.7 varus	8.0 ± 5.5 varus	.79

BMI, body mass index.

At 1-year postoperation, each patient underwent weight-bearing stereo examinations (anteroposterior [AP] and lateral directions) with a radiostereometric analysis (RSA) system at 0°, 20°, 40°, and 60° of flexion. All examinations were performed with a biplane calibration cage (RSA Biomedical, Umea, Sweden). Model-based RSA software (RSAcore, Leiden, Netherlands) was used to perform 2D/3D registration of the manufacturer's CAD models for the femoral and tibial components to each pair of x-rays for each examination. The model-based RSA approach has been demonstrated to have an excellent accuracy, with errors of 0.19 mm for translations and 0.52° for rotations [15]. Using the registered CAD models, the point of shortest distance between the femoral and tibial components on each of the medial and lateral condyles was

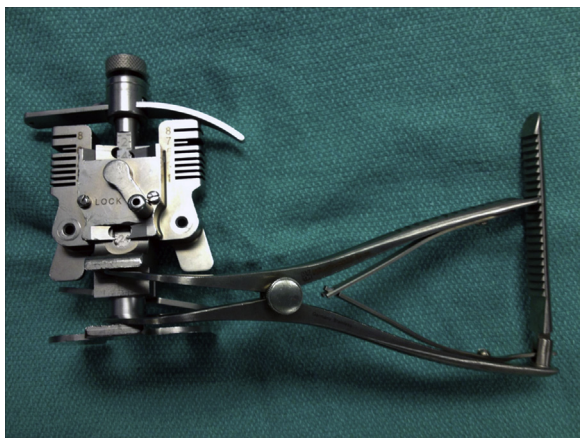

Fig. 1. Photograph of the McBride tensioner that features a central pivot and was used to create symmetric flexion and extension spaces of equal magnitude.

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