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Postoperative Changes in Soft Tissue Balance in Mobile- and Fixed-Bearing Posterior-Stabilized Total Knee Arthroplasty

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Abstract

Purpose: This prospective study was designed to evaluate the postoperative changes in soft tissue balance between Mobile- Bearing (MB) and Fixed- Bearing (FB) Posterior- Stabilized (PS) Total Knee Arthroplasty (TKA) with identical femoral components.

Methods: A total of 40 knees in 37 consecutive patients were randomly allocated to undergo either an MB PS TKA or an FB PS TKA (20 knees each). We investigated the correlation between the intraoperative soft tissue balance as evaluated by an offset- type tensor and the 1-year postoperative coronary ligament balance as assessed by stress radiographs.

Results: In terms of soft tissue balance, there were no differences in the intra- and postoperative values between the groups. At extension, the close correlation between intra- and postoperative soft tissue balance was seen in both inserts. The correlations at 90° of flexion, on the other hand, were maintained in the MB group and lost in the FB group.

Conclusion: Our results suggest that the intraoperative setting of soft tissue balance may change postoperatively. However, using this PS design, the MB insert could be more stable than the FB insert in terms of maintaining the balance postoperatively. This result may contribute to additional improvements in surgical techniques, particularly in adjusting the soft tissue balance to obtain a better outcome after TKA. (Trial registration: UMIN, UMIN000003151. Registered 8 February 2010 – Retrospectively registered, https://upload.umin.ac.jp/cgi-open-bin/ctr_e/ctr_view.cgi?recptno=R000003821).

Keywords: Arthroplasty; Knee replacement; Prostheses and implants; Surgical procedures; Guided tissue regeneration

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Introduction

The ultimate goal of Total Knee Arthroplasty (TKA) is to relieve pain and improve knee function. To achieve optimal outcomes, it is extremely important to use the appropriate surgical procedure and choose a well- designed implant [1-3]. Among the important surgical maneuvers involved, such as the soft tissue balancing, the setting of the joint line, and the patellar resurfacing, a proper balancing of the soft tissue has been recognized as an important adjustable factor for postoperative function and implant durability in TKA [4-10]. On the other hand, the intraoperative soft tissue balance in TKA could change postoperatively due to reduced swelling that increases capsular laxity, quadriceps extensibility, [11] and encapsulation [12]. Furthermore, this balance could also be influenced by varying tension during postoperative active or passive motion of the soft-tissue structures and by the geometry of the implant [13]. However, how the intraoperative soft tissue balance changes over time after TKA is poorly understood. Rotating- platform Mobile-Bearing (MB) TKA was developed to provide congruent tibiofemoral articulations to achieve Antero Posterior (AP) stability and low contact stress, and sufficient rotational laxity to permit physiological rotation with reduced torque transmitted to the tibial bone-implant interface [14]. Accordingly, this prosthesis was designed to allow the torque and shear forces that occur during weight-bearing activities to be transferred via displacement to the soft tissues [15]. This suggests that there may be differences in the postoperative soft tissue condition between MB and Fixed-Bearing (FB) inserts. The purpose of this study was to investigate the correlation between the intraoperative soft tissue balance evaluated by an offset-type tensor and the 1-year postoperative coronal ligament balance as assessed by stress radiographs in MB- and FB-Posterior-Stabilized (PS) TKA with identical femoral components.

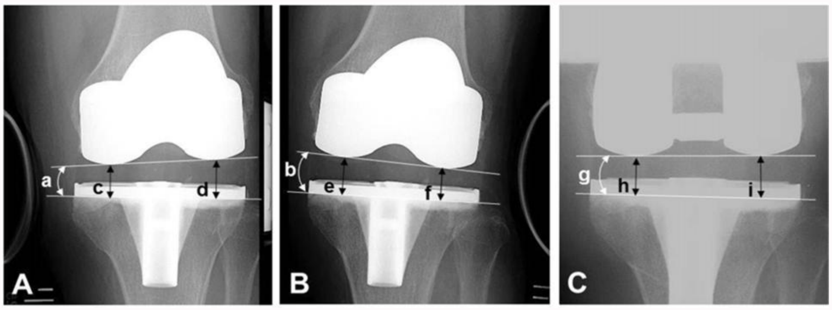

Figure 1: The postoperative assessments of the ligament balance on the varus (A) and valgus (B) stress radiographs at full extension and the stress epicondylar view radiograph at 90º of flexion (C). At extension (A and B), the joint component gap was expressed as (a+b+c+d)/4", and the ligament balance in varus as "a – b." At 90º of flexion (C), the joint component gap was expressed as "(h + i) / 2," and the ligament balance in varus as "g."

Materials and Methods

Patients

We enrolled a total of 40 knees in 37 consecutive patients that underwent a PS TKA for medial compartmental osteoarthritis of the knee between February 2010 and April 2011. The exclusion criteria used were a history of surgery in the involved side and severe deformity (>20° varus or >30° flexion contracture). There were 6 men and 31 women with an average age of 76 years (range, 64-88 years). Before surgery, we prospectively and randomly allocated 20 knees to receive an MB PS TKA (NexGen LPS Flex Mobile; Zinmmer, Warsaw, IN) (the MB group), and the other 20 knees to receive an FB PS TKA (NexGen LPS Flex Fixed; Zinmmer) (the FB group) according to the envelope method. All knees received femoral components of an identical design. There were no significant differences in the preoperative demographic data between both groups (Table 1). This study was approved by the institutional review board of the Faculty of Life Science Kumamoto University (#1033) and all patients provided their informed consent for participation in this study.

Surgical procedures

All operations were performed in the same manner, including the surgical approach, bone cuts, soft tissue balancing, and other surgical maneuvers by a single senior surgeon (E.N) who employed a measured resection technique. The patella was not resurfaced. The posterior cruciate ligament was sacrificed. Distal femoral resection was performed perpendicular to the femoral mechanical axis. The rotational angle of the femoral component was set parallel to the Surgical Epicondylar Axis (SEA) intraoperatively using our newly developed device, according to the angle between the SEA and the Posterior Condylar Line (PCL) measured on a preoperative epicondylar view radiograph of the knee. Furthermore, we removed the remaining cartilage of the femoral posterior condyle to avoid the influence of the remaining cartilage. Using this device, we can rotate evenly at 1° intervals internally and externally until reaching 7º relative to the PCL. In our previous study, the mean postoperative angular difference between the SEA and the PCL was 0.3°, ranging from -0.4° to 0.9°. This technique allowed us to establish correct rotational alignment of the femoral component, which has been recently described as 'adapted measured resection' by Luyckx et al. [16]. Subsequently, proximal tibial resection was performed with each cut made perpendicular to the mechanical axis in the coronal plane and with approximately 5° of posterior inclination along the sagittal plane. No bony defects were observed along the eroded medial tibial plateau in any of the patients. After each resection, we removed the osteophytes, released the posterior capsule from the posterior aspect of the femur, and corrected any ligament imbalances in the coronal plane using a spacer block at knee extension by appropriately releasing the medial soft tissues.

Intraoperative measurement of soft tissue balance

The measurement of the intraoperative soft tissue balance was performed using an offset-type tensor developed by Muratsu et al. [6,17]. After completing the bony resections and the appropriate soft tissue release, the tensor was fixed to the proximal tibia and fitted to the femoral trial prosthesis. The medial parapatellar arthrotomy was then temporarily repaired by applying several stitches, which allows for patellofemoral joint reduction during the measurement. The joint distraction force was set at 40 lb. (18.1 kg) using a torque drives in all patients. The joint distraction force was loaded several times until the joint gap was at a certain value to prevent creep elongation and the thigh was held to align the knee in the sagittal plane to eliminate the rotational influence. Using this device, the intraoperative joint component gap (millimeters) and ligament balance in varus (degrees) at 0° (full extension) and 90° flexion of the knee could be measured.

Evaluation

At the 1-year follow-up, the coronal ligament balance was assessed by stress radiographs of the knees using a Telos SE arthrometer (FaTelos; Medizinisch Technische, Greisheim, Germany) as well as epicondylar view radiographs with a 1.5 kg weight strapped at the ankle, according to the method described by Kanekasu et al. [18]. Anteroposterior fluoroscopic images at full extension were taken while the device was set just above the joint on the medial or lateral femoral condyle a with varus or valgus force of 15 lbs (Figure 1A and 1B).

Postoperative joint component gap: On the varus and valgus stress radiographs, the distances between the medial and lateral contact points connecting the bottom of the femoral prosthesis and a line in contact with the lower surface of the tibial prosthesis were considered to be the medial (Figure 1A-1c and Figure 1B-1e) and lateral compartment gaps, respectively (Figure 1A-1d and Figure 1B-1f). The value of the total of these four values divided by 4[(c+d+e+f)/4] and was defined as the postoperative joint component gap at full extension. Similar measurements were taken from the stress epicondylar view radiograph (Figure 1C) with the distances between the medial and lateral contact points connecting the bottom of the femoral prosthesis and a line in contact with the lower surface of the tibial prosthesis were considered to be the medial gap (Figure 1C-1h) and lateral compartment gap, respectively (Figure 1C-1i). The average of both compartment gaps [(h+i)/2] was defined as the

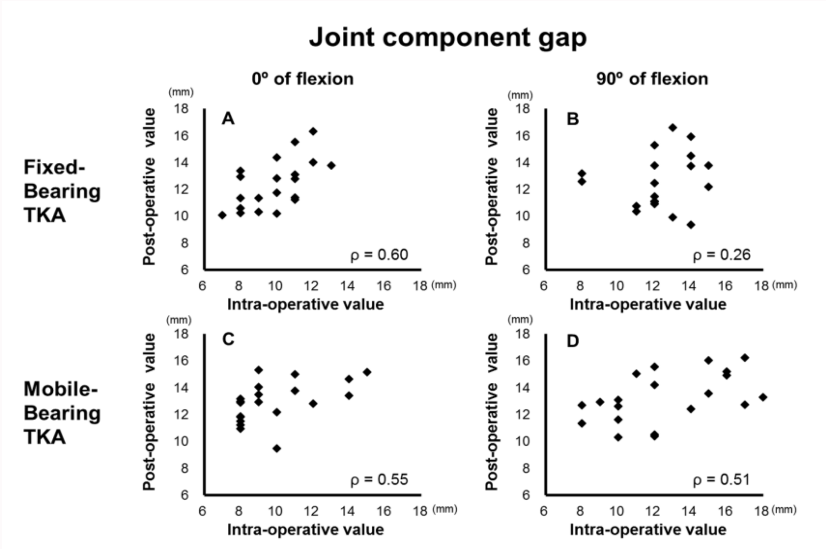

Figure 2: The correlations between the intra- and postoperative joint component gap of the fixed-bearing (FB) (A: full extension and B: 90º of flexion) and mobile-bearing (MB) groups (C: full extension and D: 90º of flexion). In the FB group, there was a significant correlation between the intraoperative value and the corresponding postoperative value at 0° (A; ρ=0.60, *p*<0.01), but at 90° of flexion, no significant correlation was found (B; ρ=0.26, *p*=0.26). On the other hand, In the MB group, a correlation at both angles was observed (C; ρ=0.55, *p*<0.05 and D; ρ=0.51, *p*<0.05, respectively).

Table 1: Preoperative demographic data in both groups.

	MB	FB	p
Number of patients	19	19	
Number of knees	20	20	
Age at surgery (years)	75 ± 7	76 ± 3	ns
Sex (male/female; patients)	2 / 17	4 / 15	ns
Side (R/L; knees)	8 / 12	7 / 13	ns
Range of motion			
Extension (degree)	6 ± 7	6 ± 5	ns
Flexion (degree)	130.0 ± 8	130 ± 9	ns
Tibiofemoral angle (degree)	185 ± 5	184 ± 7	ns

Data are shown as absolute numbers or mean values ± standard deviations. p: the probability between both groups; ns: not significant, MB: Mobile-Bearing; FB: Fixed-Bearing

postoperative component gap at 90° of flexion.

Postoperative ligament balance in varus: On the varus and valgus stress radiographs, the angles between the line in contact with the bottom of the femoral prosthesis and the line in contact with the lower surface of the tibial prosthesis were considered to be the varus (Figure 1A-1a) and valgus angles (Figure 1B-1b), respectively. The value of the varus angle minus the valgus angle (a-b) was defined as the postoperative ligament balance in varus at full extension. In addition, on the stress epicondylar view radiograph, the varus angle between the line in contact with the bottom of the femoral prosthesis and the line in contact with the lower surface of the tibial prosthesis (g) was defined as the postoperative ligament balance in varus at 90° of flexion (Figure 1C-1g).

Statistics

All statistical analyses were performed using Stat View, version 5.0 (SAS Institute Inc., Cary, NC, USA). The Spearman's correlation coefficient (ρ) was used to determine the correlations between the intraoperative and postoperative values for the joint component gap and the ligament balance at each flexion angle. In addition, the Mann-Whitney U test was used to evaluate differences between the MB and FB groups for continuous variables, while the Fisher's exact test was used to evaluate group differences in categorical variables (sex and side). A *p*-value less than 0.05 was considered statistically significant.

Table 2: Intraoperative soft tissue condition.

Flexion angle	Joint component gap (mm)			Ligament balance in varus (°)		
	FB	MB	p	FB	MB	p
0º	9.9 ± 1.7	9.9 ± 2.3	ns	1.6 ± 1.6	1.0 ± 1.6	ns
90º	12.3 ± 1.9	12.6 ± 3.2	ns	2.8 ± 2.6	2.0 ± 2.3	ns

The data are shown as mean values ± standard deviations. p: the probability between both groups; ns: not significant; MB: Mobile-Bearing; FB: Fixed-Bearing

Results

In terms of the intraoperative condition of the soft tissue, there were no statistical differences in the joint component gap and the ligament balance in varus between both groups at 0° and 90° of flexion (Table 2). There were differences in the postoperative values, but these were not statistically significant (Table 3). However, when we examined the correlation between the intra- and postoperative values, a difference was observed between the groups. In the FB group, there was a significant correlation between the intraoperative joint component gap and the corresponding postoperative values at 0° of flexion (Figure 2A) ρ=0.60, *p*<0.01 but not at 90° (Figure 2B). The intraoperative ligament balance of the FB group showed significant correlation with the corresponding postoperative values at 0° of flexion (Figure 3A).

ρ=0.46, *p*<0.05, but not at 90° of flexion (Figure 3B). On the other hand, in the MB group, the intraoperative values in both the joint component gap and the ligament balance in varus were significantly correlated with the corresponding postoperative values at 0° (Figure 2C) ρ=0.55, *p*<0.05 and (Figure 3C) ρ=0.53, *p*<0.05, respectively and 90° of flexion (Figure 2D) ρ=0.51, *p*<0.05 and (Figure3D) ρ=0.48, *p*<0.05, respectively.

Discussion

During TKA, the intraoperative soft tissue balance can be affected

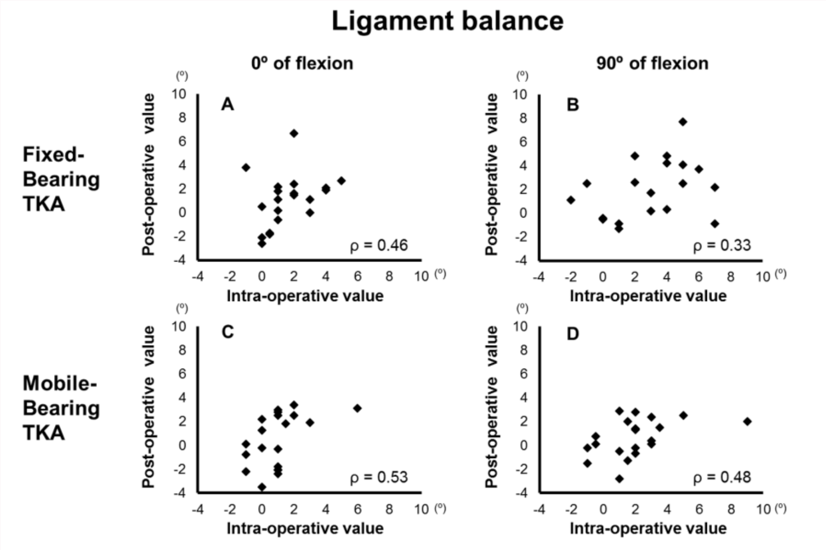

Figure 3: The correlations between the intra- and post-operative ligament balance in varus of the fixed-bearing (FB) (A: full extension and B: 90º of flexion) and mobile-bearing (MB) groups (C: full extension and D: 90º of flexion). In the FB group, there was a significant correlation between the intraoperative value and the corresponding postoperative value at 0° (A; ρ=0.46, p<0.05), but at 90° of flexion, no significant correlation was found (B; ρ=0.15, p=0.15). On the other hand, in the MB group, a correlation was found at both angles (C; ρ=0.53, p<0.05 and D; ρ=0.48, p<0.05, respectively).

Table 3: Postoperative soft tissue condition.

Flexion angle		Joint component gap (mm)				Ligament balance in varus (º)		
		FB	MB	p		FB	MB	p
0º		12.4 ± 1.8	12.9 ± 1.5	ns		1.0 ± 2.2	0.5 ± 2.2	ns
90º		12.6 ± 2.1	13.2 ± 1.9	ns		2.0 ± 2.4	0.6 ± 1.6	ns

The data are shown as mean values ± standard deviations. p: the probability between both groups; ns: not significant; MB: Mobile-Bearing; FB: Fixed-Bearing

by several factors such as the release of soft tissue, the position and geometry of the components, and the rotation of the femur relative to the tibia [19,20]. However, this amount may change postoperatively. As it has been reported to take at least 6 months for the postoperative stabilization of the soft tissue, which could possibly have an adverse effect on TKA kinematics, we focused on the 1-year postoperative changes in soft tissue balance when performing a TKA with the same femoral component design and bone cut [21]. The most important finding of this study was that there is a difference in postoperative changes in the soft tissue balance between the MB and FB groups; however, this difference is not clinically or radiologically significant. Our results showed no differences in the intra- and postoperative values between the groups. However, while correlation with postoperative values at 90° of flexion remained significant in the MB group, they were lost in the FB group. Several studies have shown a close relationship between intra- and postoperative soft-tissue balance in both FB [6,22] and MB inserts [23] at near extension, which was consistent with our results at full extension. On the other hand, at 90° of flexion, this correlation was not seen in the FB inserts [6], which is in agreement with the present results. There is no previously published data on MB inserts. In a PS TKA, the post-cam mechanism drives rollback of the femur on the tibia with flexion when both cruciate ligaments are sacrificed. In the midflexion range in particular, where the post-cam mechanism does not engage yet, some instability is suspected to occur because of the lack of a postoperative stabilizer of the anterior–posterior translation [24]. In NexGen Legacy Posterior Stabilized (LPS) Flex TKA, the angle at which the post-cam mechanism engages in vivo is approximately 95° of flexion [25]. Therefore, the angle from midflexion to 90° of flexion may expose instability inherent to this design. However, the MB insert permits free rotation at the interface of the tibial component. Indeed, a wider range of axial rotation relative to the tibial component and the subsequent internally rotated tibia was seen in the MB insert, while the tibial rotational position did not change postoperatively in the FB insert [26,27]. These could allow the knees implanted with an MB insert to be postoperatively positioned in a more properly balanced soft tissue envelope compared with the FB prosthesis [27], with subsequently less stretching of the soft tissue. This may possibly explain the difference in postoperative changes in soft tissue balance at 90° of flexion between both inserts. The previous studies using NexGen LPS Flex TKA showed some differences in post operative kinematics between the FB and MB inserts. The FB insert was located more posteriorly on the tibial baseplate compared to the MB insert at more than 45° of flexion, resulting in a more posterior femoral location during passive bending [28] or weight-bearing dynamic activities [26,29]. In addition, the varus/valgus angles in the midflexion range in the FB inserts were larger than that in the MB inserts [30-37]. These differences in kinematics may partly result from the difference in the postoperative soft tissue balance between both inserts even after similar intraoperative setting of soft tissue. There are some limitations associated with the present study. First, we evaluated only the correlations between the intra- and postoperative soft tissue balances. At the present time, we could not directly compare the absolute amounts before and after surgery because of the different methods used for each measurement. Second, our data were based only on the NexGen LPS Flex prosthesis. Therefore, our results may not be applicable to other designs. Further studies regarding various implant designs are needed to further clarify this point.

Conclusion

Although there was no direct relation with clinical outcomes as shown in the previous studies, the results of the present study have confirmed our primary hypotheses: there is a difference in postoperative changes in soft tissue balance between both bearings. Recently, some guided motion by the prosthetic design, restoring more normal and predictable kinematics, has been reported to improve postoperative subjective and objective functional results. Taking this into consideration, it is advantageous that the intraoperative setting of the soft tissue balance is maintained constant over time. Our results suggest that, in the NexGen LPS Flex prosthesis, the MB insert may be more stable than the FB in terms of maintaining the intraoperative soft tissue balance postoperatively, particularly at flexion. We believe that this result can contribute to additional improvement in surgical techniques; particularly in adjusting the soft tissue balance to obtain better out comes after TKA.

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