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The Influence of Joint Distraction Force on the Soft-Tissue Balance Using Modified Gap-Balancing Technique in Posterior-Stabilized Total Knee Arthroplasty

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ABSTRACT

Background: During modified gap-balancing technique, there is no consensus on the best method for obtaining appropriate soft-tissue balance and determining the femoral component rotation.
Methods: Sixty-five varus osteoarthritic patients underwent primary posterior-stabilized total knee arthroplasty using modified gap-balancing technique. The influence of joint distraction force on the soft-tissue balance measurement during the modified gap-balancing technique was evaluated with Offset Repo-Tensor between the osteotomized surfaces at extension, and between femoral posterior condyles and tibial osteotomized surface at flexion of the knee before the resection of femoral posterior condyles. The joint center gap (millimeters) and varus ligament balance (°) were measured under 20, 40, and 60 pounds of joint distraction forces, and the differences in these values at extension and flexion (the value at flexion minus the value at extension) were also calculated.
Results: The differences in joint center gap (−6.7, −6.8, and −6.9 mm for 20, 40, and 60 pounds, respectively) and varus ligament balance (3.5°, 3.8°, and 3.8°) at extension and flexion were not significantly different among different joint distraction forces, although the joint center gap and varus ligament balance significantly increased stepwise at extension and flexion as the joint distraction force increased.
Conclusion: The difference in joint center gap and varus ligament balance at extension and flexion were consistent even among the different joint distraction forces. This novel index would be useful for the determination of femoral component rotation during the modified gap-balancing technique.
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Accurate component placement and adequate soft-tissue balance are recognized as essential surgical principles in total knee arthroplasty (TKA) [1–3]. Especially, proper rotation of the femoral component is critical, as malrotation has been associated with many adverse sequelae such as patellofemoral (PF) instability, anterior knee pain, arthrofibrosis, and flexion instability [4–9]. However, the best method for obtaining appropriate soft-tissue balance and femoral component rotation still remains controversial [6,7,10,11]. Some favor a measured resection technique in which bony landmarks, such as femoral epicondyles, posterior femoral condyles, or the anteroposterior axis, are the primary determinants of femoral component rotation [4–6,12,13]. Others recommend a gap-balancing technique in which the femoral component is positioned parallel to the resected proximal tibia with each collateral ligament equally tensioned [7,14,15], and there are basically 2 gap-balancing sequences; a flexion gap first technique and a modified (extension gap first) technique [16]. Dennis et al [15] showed the gap-balancing technique resulted in postoperative better coronal stability rather than a measured resection technique. Intraoperative soft-tissue balancing was originally described by Freeman et al [17] and Insall et al [2] and is an established method for preparing equal rectangular flexion and extension gaps by releasing soft-tissue structures around the knee. However, the previous studies showed soft-tissue could be easily

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extended in low soft-tissue tension and hardly extended in high tension because of the tension properties of soft-tissue complex during TKA [18], and another study demonstrated that larger joint distraction forces led to larger varus ligament balance and larger joint center gap (more trapezoidal gap) because of the difference in soft-tissue stiffness between medial and lateral compartments, which could affect the rotation of the femoral posterior condyle resection during gap-balancing technique [19]. In gap-balancing technique, the applied joint distraction forces during the assessment are different among surgeons, and there is no consensus so far; therefore, the objective and consistent index which is not affected by the joint distraction forces will be ideal for gap-balancing technique to avoid the malrotationing of femoral component.

To assess the intraoperative soft-tissue balance that reflects postoperative condition after TKA, an offset-type tensor was originally developed [20]. This tensor enables surgeons to assess soft-tissue balance after reduction of the PF joint and with the femoral component in place. Using this tensor, the surgeons can measure the joint center gap (component gap, millimeter) and varus ligament balance (varus angle, °) [21–23]. The previous study assessed the influence of joint distraction forces during the measured resection technique, and the evaluation of the flexion gap was done after the femoral posterior condyles resection [19]; so, it is still unknown about the influence of joint distraction forces on intraoperative gap measurement before the femoral posterior condyles resection during the modified gap-balancing technique. Therefore, the purpose of this study is (1) to investigate the influence of the joint distraction force on intraoperative soft-tissue balance using modified gap-balancing technique in posterior-stabilized (PS) TKA and (2) to develop the novel index for the determination of femoral component rotation which could be useful for the modified gap-balancing technique. It has been shown that medial instability would cause postoperative pain [24] and more abnormal kinematics [25], and lateral laxity of the knee joint is physiological [26,27]. Based on these previous findings, excessive medial release was not performed and lateral laxity of approximately 5° in extension gap was allowed, essentially making a trapezoidal gap. To perform "medial preserving gap technique" focusing on the medial stability, the difference in the joint center gap and varus ligament balance (the value at flexion minus the value at extension) can be used for creating equal trapezoidal gap in extension and flexion in the present study (Fig. 1).

The previous study demonstrated the stepwise increase of the varus ligament balance and joint center gap as the joint distraction forces increased between osteotomized surfaces [19]; so, based on these findings, we hypothesized that the difference in the joint center gap and varus ligament balance at extension and flexion would be consistent among the different distraction forces, although the joint center gap and varus ligament balance would increase stepwise with the increase of the joint distraction forces.

Materials and Methods

Sixty-five consecutive varus osteoarthritic patients who met the following criteria and underwent primary PS TKA between July 2010 and July 2013 were prospectively enrolled in this study. The patient population comprised 58 females and 7 males, with a mean age of 74.6 ± 5.8 years. The average preoperative coronal plane alignment was 12.4° ± 5.0° in varus, and the average preoperative knee extension and flexion angles were −7.4° ± 9.4° and 107.4° ± 19.5°, respectively. The inclusion criteria were the presence of substantial pain and loss of function due to osteoarthritis (OA) of the knee. The exclusion criteria were the presence of knees with valgus deformity, severe bony defects that require bone graft or augmentation, and/or active knee joint infection; patients undergoing revision TKA were also excluded. Each surgery was performed by the same surgeon—the senior author (H. M.)—using PS TKA (NexGen LPS-Flex; Zimmer, Inc, Warsaw, IN) with a standardized surgical technique. The hospital ethics committee approved the study protocol, and the patients provided informed consent for participation in the study.

Offset Repo-Tensor

The OFR tensor (Zimmer, Warsaw, IN) consists of 3 parts: an upper seesaw plate, a lower platform plate with a spike, and an extra-articular main body, as previously described [19,21–23,28]. This device is designed to facilitate the measurement of ligament balance and joint center gap, both before and after femoral trial

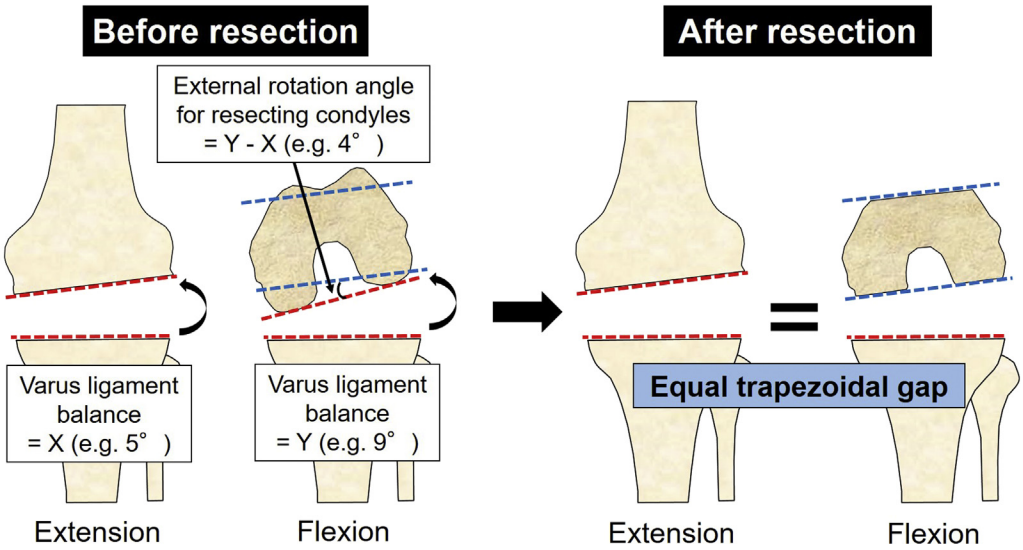

Fig. 1. A schema of creating the equal extension and flexion trapezoidal gaps. If the external rotation angle for resecting femoral posterior condyles is determined based on the new index, the difference in varus ligament balance at extension and flexion (Y − X), the equal extension and flexion trapezoidal gaps will be created after the resection of the femoral posterior condyles.

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