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Review article

Ligament balancing in total knee arthroplasty—Medial stabilizing technique

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Abstract

Ligament balancing is one of the most important surgical techniques for successful total knee arthroplasty. It has traditionally been recommended that medial and lateral as well as flexion and extension gaps are equal. This article reviews the relevant literature and discusses the clinical importance of the aforementioned gaps. Current evidence indicates that achieving medial stability throughout the range of motion should be a high priority in ligament balancing in total knee arthroplasty. Finally, the medial stabilising surgical technique, which aims to achieve good medial stability in posterior cruciate-retaining total knee arthroplasty, is introduced.

Keywords: alignment; biomechanics; implant design; ligament balancing; total knee arthroplasty

Introduction

Total knee arthroplasty (TKA) involves resection of the medial and lateral menisci; moreover, the anterior cruciate ligament is usually resected, and the posterior cruciate ligament (PCL) is sometimes sacrificed. Therefore, knee stability should be achieved by the remaining ligamentous structures and articular surface geometry. Varus–valgus and rotational stability can be obtained mainly by proper tensioning of collateral and capsular ligaments.[1] Therefore, surgical technique is critical for maintaining knee stability after TKA. This review article summarises previous reports and our studies, and discusses the most important factors in ligament balancing in TKA for osteoarthritis with varus deformity. Furthermore, a surgical technique for achieving adequate medial stability is introduced.

Principles of ligament balancing in TKA

Recent technological advances have enabled the accurate evaluation of soft tissue tension intraoperatively.[2] However, the goal of soft tissue balancing is unclear. The classical concept of TKA is the achievement of equal medial and lateral gaps as well as equal flexion and extension gaps. However, this concept and whether it is possible in all cases remains controversial. In this article, the concept of ligament balancing is subcategorised into four parts: medial extension, medial flexion, lateral extension, and lateral flexion gaps.

Medial extension gap: how tight/loose can the knee be left?

How tight the knee can be left in extension intraoperatively to avoid postoperative flexion contracture remains unclear.[3] A few studies have evaluated the relationship between intraoperative soft tissue tension and postoperative extension angle.[4] Therefore, we evaluated the effect of extension gap on postoperative flexion contracture.[5] In that study, intraoperative extension gap was evaluated in 75 knees with varus deformity after TKA using the NexGen LPS (Zimmer, Warsaw, IN, USA). The gap was measured with a femoral component using a tension device applying a distraction force of 178 N. A "component gap" was defined as the distance calculated by subtracting the selected thickness of the tibial component, including the polyethylene liner from the measured gap.

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Postoperative extension angle was measured by radiography. The knee was extended by the patient's own leg weight when the heel was raised 10 cm above the table. Flexion contracture was defined as the angle between the anatomical axis of the distal femur and the proximal tibia exceeding 5°. As a result, the tight group (medial component gap: <0 mm) showed 10% flexion contracture at 1 year postoperatively, the slightly tight group (medial component gap: 0–1 mm) still had 8% flexion contracture, and the group with knees with >1 mm medial component gap showed no flexion contracture. These results suggest that >1 mm laxity at the medial side after implantation is necessary to avoid flexion contracture.

How loose can the knee be left? First and foremost, the patient should not feel unstable. One benchmark would be the stability of normal knees. We previously measured knee laxity in normal knees by stress radiography and found that the medial side was opened 2.4° when a valgus stress of 147 N was applied.[6] Ishii et al[7] report that excellent clinical results were achieved in patients with 3–4° valgus laxity after TKA. These studies suggest that 2–4° laxity does not make patients feel unstable after TKA. Therefore, we suggest that medial extension laxity should be 1–3 mm to avoid flexion contracture and a feeling of instability (note that 1° medial laxity equals approximately 1.05 mm when the transverse diameter of the tibia is 80 mm).

Medial flexion gap: should it be adjusted to the extension gap?

A clinical study by Takayama et al[8] indicates that tight flexion decreases range of motion after TKA. In addition, Jeffcote et al[9] report that a flexion gap that is more than 2 mm greater than the extension gap decreases tibial forces in deep knee flexion. Therefore, flexion tightness should definitely be avoided, but how much looseness can be tolerated? In normal knees, at the medial side, knee laxity at flexion is almost equal to knee laxity in extension or slightly lax at 1–2 mm.[10] We previously evaluated the effect of looseness in knee flexion on clinical outcome in 50 patients after TKA.[11] Stress radiographs were taken while a lateral traction force of 50 N was applied perpendicular to the lower leg at 80° knee flexion, and the angle between a line tangential to the femoral condyles and a line through the tibial joint surface was measured. Patient satisfaction, symptoms, and knee function according to the new Knee Society scoring system were compared between the knees with ≥3° medial flexion laxity (medial loose group) and those with <3° medial flexion laxity (medial tight group). The scores of the medial loose and tight groups were 22 and 30 for satisfaction (out of 40), 16 and 20 for symptoms (out of 25), and 19 and 24 for standard activities (out of 30), respectively. Our fluoroscopic analysis also showed that a greater medial flexion gap caused larger anterior translation in knee flexion.[12] On the basis of these studies, we recommend that the medial flexion gap should be close to the medial extension gap to achieve near-normal knee conditions as well as to improve postoperative function and patient satisfaction.

Lateral extension gap: should it be equal to the medial side?

Our study of normal knees shows that the lateral side should be 2.5° laxer than the medial side.[6] Here, we discuss the case of osteoarthritic knees. We investigated knee laxity of osteoarthritic knees during TKA.[13] In that study, the extension gap was measured after the distal part of the femur and proximal part of the tibia were resected. The patients were divided into the mild, moderate, and severe varus groups, which had preoperative hip–knee–ankle angles of <10°, 10–20°, and >20°, respectively. Measurements were made after removing osteophytes with a distraction force of 178 N. The results show that lateral soft tissue laxity increased with increasing severity of knee deformities. However, the medial side did not contract with increasing varus deformity. These results suggest that release on the medial side is unnecessary to make a space for implant replacement, even in severely deformed knees.

However, gap imbalance increases with increasing knee deformity up to 5 mm, prompting the determination of solutions for this imbalance. One of the classical methods for treating this situation is medial release. Krackow and Mihalko[14] report that complete release of the medial collateral ligament (MCL) increases medial instability to 6.9° in full extension but to 13.4° in 90° of flexion. Furthermore, Mullaji et al[15] state that releasing the MCL by 6–8 cm enlarges the medial extension and flexion gaps to 2.8 mm and 7.0 mm, respectively. These findings highlight the difficultly in managing extension imbalance by medial release alone; medial release would cause flexion instability in such cases.

Another important point is how much ligament imbalance can be left. Here, we focus on lift-off motion, because joint laxity theoretically increases the risk of lift-off motion. As lift-off motion of the femoral component possibly increases wear of the articular surface,[16] it should be avoided after TKA. Hamai et al[17] evaluated the effect of static knee instability by stress radiography on dynamic lift-off motion in fluoroscopy; the static varus–valgus laxity or differences in the laxities (i.e., imbalance) on the stress radiograph did not influence lift-off. Moreover, 90% of their patients had neutral alignment. We also evaluated effects of alignment and ligament balance on lift-off motion using computer simulations, which have recently been used and validated in the field of TKA.[18–24] We used KneeSIM software (LifeMOD/KneeSIM 2010; LifeModeler Inc., San Clemente, CA, USA) to evaluate the effects of alignment and laxity on lift-off motion. Our results show that lift-off motion occurs with 5° varus alignment, or with a combination of 2° varus deformity and 2 mm lateral laxity.[25] However, no lift-off motion was detected in knees with neutral to 1° varus malalignment even when the knees had 5 mm lateral laxity.

In summary, lateral laxity of 3° is close to normal conditions, which would not cause a feeling of instability. Lateral laxity theoretically increases the risk of lift-off motion, however, these risks would decrease with neutral alignment. Lateral laxity up to 5° in extension would be acceptable when neutral alignment is achieved.