Arthroplasty Today 25 (2024) 101304

Contents lists available at ScienceDirect

Arthroplasty Today

journal homepage: http://www.arthroplastytoday.org/

Surgical Technique

Does Selective Posterior Tibial Slope Technique in Cruciate-Retaining Total Knee Arthroplasty Result in the Elimination of Posterior Cruciate Ligament Management?

Takashi Nakamura, MD *, Ryo Takamatsu, MD, Hideyuki Aoki, MD, Hiroshi Takahashi, MD

Department of Orthopedics, Toho University Omori Medical Center, Tokyo, Japan

ARTICLE INFO

Article history:
Received 15 December 2022
Received in revised form
20 April 2023
Accepted 5 November 2023
Available online xxx

Keywords:
Cruciate-retaining total knee arthroplasty
Posterior tibial slope
Femoral posterior condylar offset
Patient-reported outcome measures

ABSTRACT

In cruciate-retaining total knee arthroplasty (CR-TKA), intraoperative posterior cruciate ligament (PCL) management is necessary because retention of optimum PCL tension with high reproducibility is difficult. If PCL management is not performed appropriately, problems such as postoperative pain, poor range of motion, and a feeling of instability may occur. The posterior tibial slope (PTS) has a major influence on the tension of the PCL in CR-TKA. Changes in femoral posterior condylar offset also influences PCL tension in CR-TKA. We designed a surgical procedure in which the PTS is adjusted in association with the posterior condylar offset during surgery. The postoperative clinical results of the primary total knee arthroplasty 159 knee performed by this procedure were favorable. In addition, none of the knees required management of PCL. In our procedure, PCL management, which is the main problem in CR-TKA, is not necessary, and this may be the main advantage of the new procedure.

Introduction

The posterior tibial slope (PTS) has a major influence on the tension of the posterior cruciate ligament (PCL) in cruciate-retaining total knee arthroplasty (CR-TKA) [1,2]. However, there is no specific method to adjust the PTS for retention of optimum PCL tension in CR-TKA, and the PTS is set without consideration of the intraoperative PCL tension. Thus, after CR-TKA using the measured resection technique, intraoperative PCL management is necessary because retention of optimum PCL tension with high reproducibility is difficult. If PCL management is not performed appropriately, problems such as postoperative pain, poor range of motion, and a feeling of instability may occur [3-6]. There are various techniques for managing PCL, such as partial separation [7,8] and increasing tibia posterior tilt [9,10]. However, the judgment of the PCL management is based on the subjective evaluation of surgeons, due to the inability to evaluate PCL tension quantitatively during surgery. This may be a major cause of difficulty in securing a stable clinical outcome in CR-TKA and a reason for differences in clinical outcomes among surgeons.

An increase in femoral posterior condylar offset (PCO) also influences PCL tension in CR-TKA, similar to that for the PTS [11,12]. Kang et al. [13] showed that an increase in PCL tension with an increase in PCO was improved by increasing PTS in a computer simulation using a finite element model. This suggests that PTS and PCO have a mutual influence on PCL tension in CR-TKA; that is, setting PTS and PCO in association with each other may enable adjustment of PCL tension to an optimum. If PTS can be adjusted in association with PCO so as to optimize PCL tension, intraoperative PCL management may be unnecessary. Thus, with the aim of retaining the optimum PCL tension with high reproducibility, we designed a new surgical procedure (the selective posterior tibial slope technique) that allows selective adjustment of PTS and PCO relative to each other during surgery. This technique is a method that seems to have been the measured resection technique in CR-TKA.

Surgical technique

Selective posterior tibial slope technique

The new surgical procedure is applied through a medial parapatellar approach and starts with femoral osteotomy following the

* Corresponding author. Department of Orthopedics, Toho University Omori Medical Center, 6-11-1, Omori-Nishi, Ota-ku, Tokyo 143-8541, Japan. Tel.: +81 3 3762 4151.

E-mail address: takashin@med.toho-u.ac.jp

https://doi.org/10.1016/j.artd.2023.101304

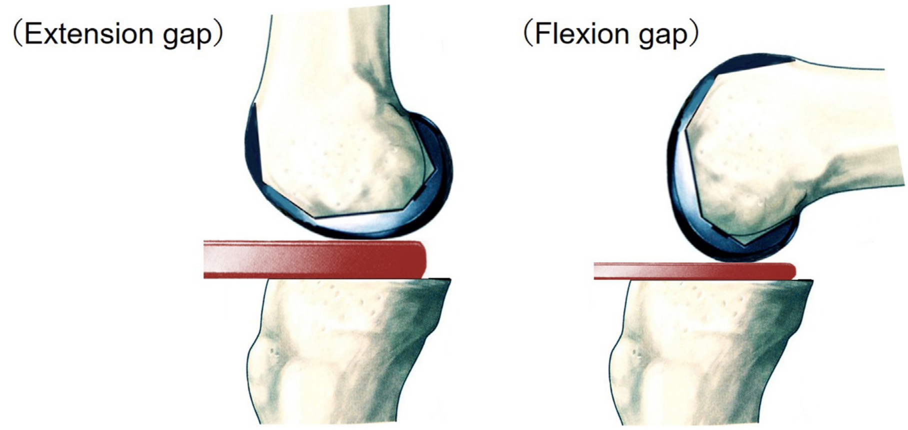

Figure 1. Check the gap difference with changing the thickness of spacer blocks every 1 mm by 2-finger technique. The extension gap is normally larger than the flexion gap because no posterior slope is added to the tibia. Δgap = extension gap - flexion gap.

measured resection technique in primary total knee arthroplasty. The osteotomy amount for the distal femur is set at the same thickness as that of the component, but we use the sulcus-cut technique [14] because wear of the articular cartilage and deformation are present on the joint surface. The anterior reference is used to determine the femoral component size. The surgical epicondylar axis is used as an index of femoral rotational alignment, with measurement of the condylar twist angle on computed tomography images before surgery as a reference for identification of the surgical epicondylar axis.

After completion of femoral osteotomy, the femoral trial is set and all osteophytes overhanging from the posterior condyle of the femoral trial are resected using a curved chisel. Tibial osteotomy is applied vertically to the tibial axis using an intramedullary alignment rod. For the tibial osteotomy level, a device dedicated to the femoral trial is attached to a level at which an 8-mm extension gap can be prepared. The extension gap is defined as a component gap at the full extension of the knee. Since the thickness of the tibial tray of the Triathlon (Stryker, Mahwah, New Jersey) is 2 mm and the thinnest thickness of the polyethylene insert is 7 mm, an extension gap of at least 9 mm is necessary. However, an extension gap that is smaller by 1 mm (8 mm) is purposely prepared in consideration of the influence of additional osteotomy on the extension gap (described below) because osteotomy is applied to the tibia in flexion gap preparation in this surgical procedure. When the tibial osteotomy is applied, in which bone tissue at the PCL insertion is protected in an island shape.

After completion of tibial osteotomy, the tibial trial is set to the tibial cut surface, and the tibial component size is determined. The size may be the same as that on the femoral side or one size smaller in many cases. Since the ligament balance affects gap creation, the tibial attachment of the MCL deep layer is released during tibial osteotomy, and all overhanging osteophytes medial to the tibial trial are removed. Ligament balance is confirmed using a spacer block, and medial release is added if the spacer block shows an extreme medial pivot pattern. After balancing the ligaments, the femoral trial is set again, the patella is placed in the reduction position, and the appropriate extension gap is measured using an offset spacer with thickness varying every 1 mm. After measurement of the extension gap, the knee joint is placed in 90° flexion, and the procedure progresses to the measurement of the flexion gap, which is defined as the component gap at 90° flexion. Similar

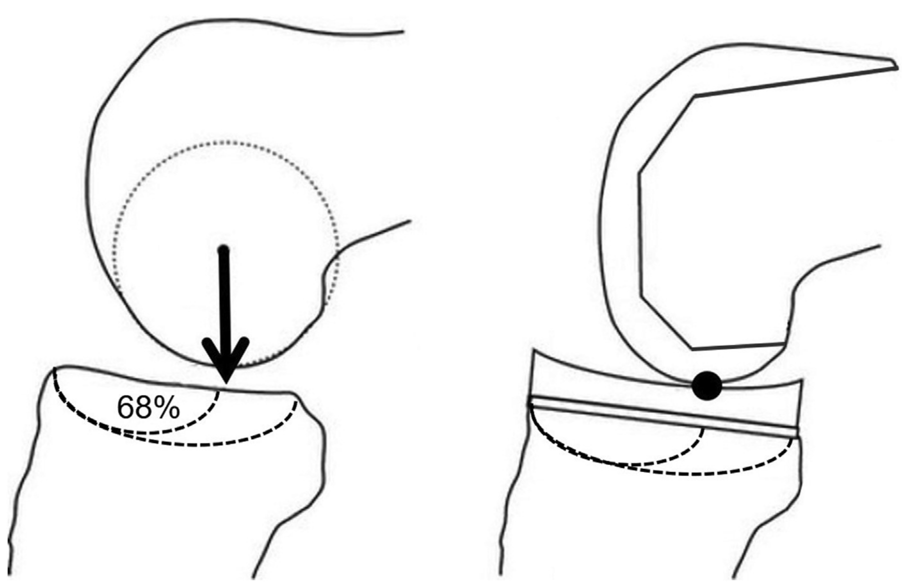

Figure 2. The femoral medial condylar contact point in a normal knee is present at two-thirds (68%) of the anteroposterior diameter of the tibia [2,3]. This information was used in design of the surgical procedure.

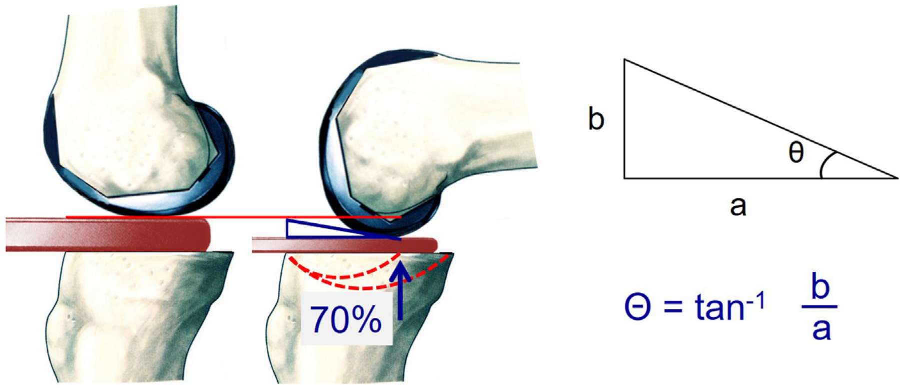

Figure 3. The hypotenuse angle (Θ: corrected posterior tibial slope angle) was calculated using an inverse trigonometric function with 70% of the anteroposterior diameter of the implant as the base length (a) and Δgap as the height (b).

to the measurement of the extension gap, the patella is placed in the reduction position and the appropriate flexion gap is measured using an offset spacer with thickness varying every 1 mm. The appropriate extension/flexion gap is defined as a gap consistent with the 2-finger technique used in unicompartmental knee arthroplasty [15]; that is, a spacer block held with 2 fingers can be smoothly taken in and out.

Since the PCL is conserved and no posterior slope is added in tibial osteotomy, the extension gap is normally larger than the flexion gap at this stage. The difference between the extension and flexion gaps is defined as Δgap (Fig. 1). In a normal knee, the femur and tibia make contact at about a 70% position from the anterior tibial joint surface when the PCL status is favorable [16,17] (Fig. 2). To make the flexion gap at 70% from the anterior tibial joint surface equal to the extension gap, the hypotenuse angle is calculated using an inverse trigonometric function with Δgap as the height and 70% of the anteroposterior diameter of the tibial component as the base (Fig. 3). The calculated hypotenuse angle allows PTS to be adjusted relative to PCO to retain optimum PCL tension. Thus, using a dedicated device with variation by 1° corresponding to the hypotenuse angle (Fig. 4), a posterior slope is added to the tibia to complete preparation of the flexion gap (Fig. 5). In this process, it is also necessary to confirm the tibial rotational alignment, which is determined using Akagi's line [18] and one-third medial of the tibial tuberosity as landmark indices.

Discussions

Since a conserved PCL serves as a joint gap stabilizer in flexion in CR-TKA, the flexion gap does not normally become larger than the extension gap, unlike in PCL-substituting TKA [19]. Therefore, the PTS is important to secure the flexion gap. However, no consensus on the PTS in CR-TKA has been reached, although it is set at about 5-7° in many cases, which may refer to the PTS of a normal knee based on the joint line theory [20,21]. However, the correctness of this angle is unclear because there are racial and individual variations in PTS [22-25]. Thus, despite the importance of the PTS in CR-TKA to secure the flexion gap and retain appropriate PCL tension, the only anatomical consideration in setting the PTS using the measured resection technique refers to a normal knee, and PCL tension during surgery is not considered.

Adjustment of PTS and PCO in association with each other was based on the femorotibial joint contact point. In a normal knee, PCL tension increases to its highest at about 90° flexion, and the position of this contact point is controlled within a flexion range of 60-120° [26,27]. When PCL tension is favorable, the femorotibial joint medial contact point at 90° flexion is present at about 70% of the anteroposterior tibial diameter [16,17], and there is a close relationship between PCL tension and the contact point. Similarly, changes in the contact point accompanying PCL tension [28] and setting the contact point after surgery to that before surgery to

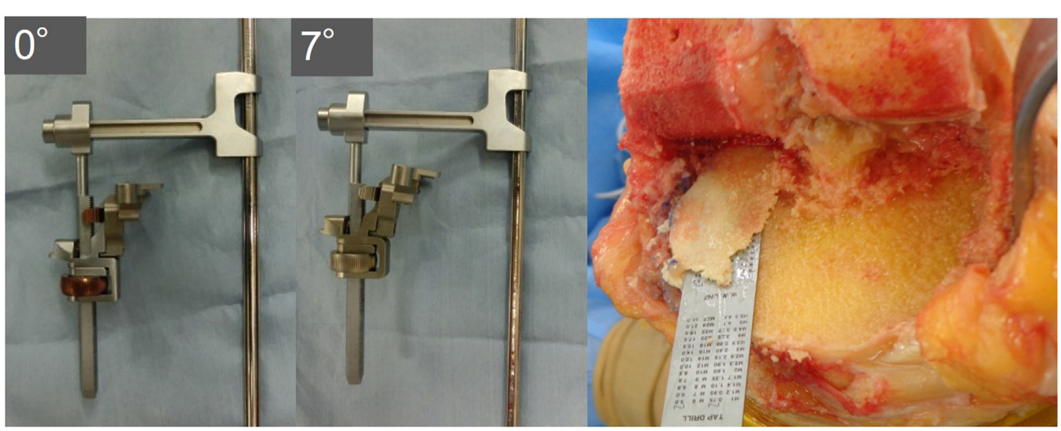

Figure 4. Based on the calculated hypotenuse angle, preparation of the flexion gap was completed using a dedicated device with angle variation of 1°. The device is available from 0° and 9°. For reference, photographs with angles set at 0° and 7° are presented.

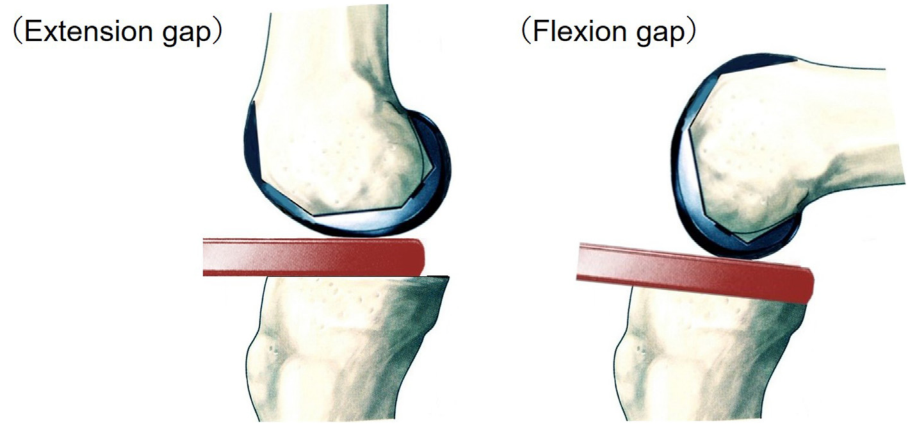

Figure 5. PTS can be adjusted in association with PCO so as to optimize PCL tension in this surgical technique. Although the PTS varies from case to case, it is not necessary to manage PCL because the PTS is adjusted based on the tension of the PCL. PCL, posterior cruciate ligament; PCO, posterior condylar offset; PTS, posterior tibial slope.

adjust PCL tension appropriately [29] have been reported in CR-TKA; that is, the relationship between PCL tension and femorotibial joint contact point in CR-TKA can be viewed as the same as that in a normal knee, which is the basis of the design of our surgical procedure.

In our surgical procedure, the preparation of the extension gap is completed after the preparation of the flexion gap. Thus, the addition of osteotomy of the tibia is necessary to prepare the flexion gap, and the extension gap increases with the preparation of the flexion gap, which is a problem in the procedure. However, an increase in the PTS influences both gaps [30], with estimated increases of the extension gap of 0.5 and 0.6 mm on the medial and lateral sides, respectively, with the addition of every 1° to the PTS. For example, in preparing a flexion gap when 5° is added to the PTS, the medial extension gap increases by 2.5 mm. However, as described previously, an extension gap smaller by 1 mm than the originally necessary extension gap is prepared in our procedure. Therefore, the actual change remains as a 1.5-mm increase, which does not make the extension gap excessively loose. In addition, the dedicated device for the PTS permits fine adjustment of the osteotomy level, which reduces the influence of the surgical procedure on the extension gap.

The postoperative clinical results and postoperative range of motion of the primary TKA 159 knee performed by this procedure were favorable. In addition, none of the knees required management of PCL. The knee joint has a complex structure with contrary functions requiring stability and flexibility, and the ligaments play an especially important role in these functions. Given these essential roles of the ligaments, CR-TKA using the measured resection technique is a superior surgical procedure with physiological stability. In our procedure, PCL management, which is the main problem in CR-TKA, is not necessary, and this may be the main advantage of the new procedure. The current study also provides scientific data for the standardization of the surgical procedure for CR-TKA.

Summary

The PTS in CR-TKA should not be set simply by simulating the anatomical morphology but should be established in association with the PCO to achieve optimum PCL tension. This technique, which can selectively adjust the PTS in relation to the PCO during surgery so that the tension of the PCL can be maintained optimally with high reproducibility, is considered to be a useful method for CR TKA.

Acknowledgments

The authors thank Y Nakamura, T Miyata, and Y Sakamoto for article preparation assistance.

Conflicts of interest

The authors declare there are no conflicts of interest.

For full disclosure statements refer to https://doi.org/10.1016/j.artd.2023.101304.

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