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A Comparison of 2 Tibial Inserts of Different Constraint for Cruciate-Retaining Primary Total Knee Arthroplasty: An Additional Tool for Balancing the Posterior Cruciate Ligament

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A B S T R A C T

Background: Frequently, a normal posterior-cruciate ligament (PCL) is removed at the surgeon's discretion, converting the normal 4-ligament knee to a 2-ligament knee, thus eliminating the need to balance all 4 ligaments. The development of modular tibial components has led to the availability of differing polyethylene inserts that permit adjustment to the flexion gap independent of the extension gap, permitting PCL balancing not previously available. The purpose of this study is to analyze a specific cruciate-retaining (CR) prosthesis which has 2 polyethylene inserts intended for CR knee use.
Methods: Between February 2004 and February 2013, the senior author (R.H.E.) has performed 930 total knee arthroplasties using the CR flat insert and 424 knees using the CR lipped insert. The inserts were selected during surgery, based on the assessed tension and function of the PCL. The patients were followed up as part of a prospective total joint program with the Knee Society clinical scoring, range of motion, complications, revisions, preoperative coronal deformity, gender, body mass index, and status of the anterior-cruciate ligament intraoperatively.
Results: The average Knee Score was 92.4 for the flat group and 92.1 for the lipped group. Average knee flexion was 116.2° for the flat group and 114.4° for the lipped group ($P = .2$). Average knee extension (flexion deformity) was 2.1° for the flat group and 0.9° for the lipped group
Conclusion: The results reported here show that clinical outcomes and survivorship were no different for either insert option, leading to indirect evidence that appropriate soft tissue balance had been achieved.

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There is no consensus in the joint arthroplasty community as to the role of the cruciate ligaments in total knee arthroplasty. With rare exception, total knee prosthesis's in the United States are intended for use without an anterior-cruciate ligament (ACL). Although in many knee arthroplasties the ACL is absent, a functional ACL is removed in the course of performing some total knee arthroplasties. The operating surgeon has the choice of retaining or removing the posterior-cruciate ligament (PCL). Total knee prostheses that retain the native PCL are commonly termed a *cruciate-retaining knee* (CR knee). Total knee prostheses that remove the native PCL but substitute it for the function of the ligament are termed a *posterior-stabilizing knee* (PS knee). In the normal knee, an intact PCL provides primary restraint to posterior translation of the tibia, especially at 90° of flexion, making the PCL a key stabilizer of the flexion gap of the knee after total knee arthroplasty [1].

On occasion, cruciate ligaments are damaged from underlying arthritic degeneration or prior trauma, making it logical to remove them, as pathologic structures that are unable to function normally. Frequently, a normal PCL is removed at the surgeon's discretion seeking to simplify the task of total knee arthroplasty, converting the normal 4-ligament knee to a 2-ligament knee, thus eliminating the need to balance all 4 ligaments. Removing the PCL also eliminates the secondary functions of the PCL such as restraining external rotation in extension, restraining varus/valgus alignment (which aids in coronal plane movement), and providing support if there is collateral deficiency [1], which are all beneficial attributes for total knee arthroplasty and not provided in the PS knee. Andriacchi and Galante [2] argue that maintaining the PCL after total knee arthroplasty should improve range of motion, reduce stress on the bone cement interface, and improve stair climbing efficiency.

In addition, PS designs also have some negative features not seen as frequently in CR knees [3,4]. These include anterior crepitation as the extensor mechanism travels across the box in the femoral component, which can progress to a patella clunk syndrome [3], whereby a synovial nodule catches in the box, on occasion requiring surgery for correction. The high post in PS designs can impinge in the femoral box

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causing accelerated polyethylene wear [4]. Despite these disadvantages, the concern with the CR knee in the eyes of many surgeons is that it is difficult to achieve a functional PCL. A biomechanical cadaver study by Mahoney et al [5] has shown that normal PCL strain was achieved in only 37% of CR knees after surgery.

The problem lies in the techniques to fine tune PCL function, which have been subpar. Scott and Chmell [6] have written that if the PCL is neither too loose nor too tight, then the tension is clinically appropriate. However, there have not been tools in the past that consistently attain this acceptable tension, which would in theory require either tightening or loosening depending on the circumstances. A tight PCL would warrant ligament releasing, although this has been considered difficult to perform [6,7], or alternatively more bone could be resected. Techniques to selectively tighten the PCL have not been discussed, other than using techniques that tighten both the flexion and extension gaps equally by symmetrically increasing the size of the tibial component, which may not be necessary or desirable.

The development of modular tibial components has led to the availability of differing polyethylene inserts that permit adjustment to the flexion gap independent of the extension gap, permitting PCL balancing not previously available. The purpose of this study is to analyze a specific CR prosthesis which has 2 polyethylene inserts intended for CR knee use. These polyethylene inserts allow for fine tuning of the tension in the flexion gap separately from the extension gap, and the study analyzes the comparative use of these 2 designs, defining any clinical setting which favors the use of one insert over the other. The hypothesis of this study is that the clinical outcomes for each insert should be similar, if the goal of optimal soft tissue balance has been achieved.

Methods

The senior author has used the Vanguard Complete total knee prosthesis (Biomet, Inc, Warsaw, Indiana) for primary knee arthroplasty since February 2004. The Vanguard is a comprehensive design with both CR and PS components. The chief author's preference is to perform a CR knee arthroplasty if satisfactory soft tissue balance can be achieved. In the setting of profoundly deranged knee kinematics and resulting abnormal ligaments, or when in the judgment of the surgeon the PCL cannot be satisfactorily balanced, a posterior-cruciate substituting design (PS knee) was used.

Cruciate-retaining inserts available with the Vanguard CR knee are both flat in the coronal plane but differ in the sagittal, anterior-posterior, plane with a CR "flat" insert with 3° of posterior sloping and no lipping, and a CR "lipped" insert with an elevated posterior lip and no sloping. The posterior lip is 2 to 3 mm in height (increases with the size of the insert) such that in the absence of sloping, plus the lip, there is an additional 4 to 5 mm of polyethylene in the posterior dimension of the tibial insert, with no change in the anterior dimension. The intercondylar eminence and anterior shape are the same for each design (see Fig. 1). Knee kinematics cause the femur to articulate on the front of the tibial insert in extension, then to rollback on the tibial surface to the back of the tibial insert with knee flexion. The added polyethylene to the posterior insert serves to tighten the PCL (and thereby the flexion gap), but does not change the dimensions of the extension gap.

Between February 2004 and February 2013, the senior author (R.H.E.) has performed 1354 primary CR total knee arthroplasties: 930 total knee arthroplasties using the CR flat insert and 424 knees using the CR lipped insert. The inserts were selected during surgery, based on the assessed tension and function of the PCL. The patients were followed up as part of a prospective total joint program with the Knee Society clinical scoring, range of motion, complications, revisions, preoperative coronal deformity, gender, body mass index (BMI), and status of the ACL at surgery. For patients who had not returned within 2 years, a mailing was done to update the clinical scoring and survivorship analysis. Because the 2 CR bearing configurations do not have any radiographically distinguishing features, the postoperative clinical assessment was done without knowledge of the type of bearing used. Of the total series, 1078 knees have completed follow-up data allowing for clinical assessment (Knee Society scores completed and considered in the statistical analysis; 741 flat and 337 lipped), with an average follow-up of 3 years for the CR flat inserts and 3.5 years for the CR lipped. Statistical analysis was done using the Student *t* test for interval data and the χ^2 test for categorical data. Survivorship analysis was done by Life Table Method.

PCL Balancing Technique

The leading author conducts a primary total knee arthroplasty with a modified measured resection technique, as originally described by Hungerford [8], cutting the femur first and putting back the equivalent amount of implant as the bone resected, such that the joint line is maintained anatomically. Coronal femoral position is determined by using an intramedullary alignment rod with an assessment of the standing long-leg radiographs. Most knees were cut at 3° to 5° of valgus. The goal is to restore the mechanical axis of the leg to neutral, with a line passing from the femoral head to the ankle passing through the central one-third of the tibia, as described by Kennedy and White [9]. Femoral component rotation was determined by the transepicondylar axis in combination with the AP axis of the femur, with the goal of a symmetrical flexion gap and neutral rotation of the trochlea.

The tibial resection was perpendicular to the mechanical axis of the tibia, using extramedullary guides, with 0 to 5° of posterior slope, in order to avoid disrupting the insertion of the PCL on the tibia. With this bone resection, paying attention to the bone removed in relationship to the dimensions of the implants placed, additional soft tissue manipulation is usually minimal. In extension, fine tuning of the collateral ligament balance is done by subperiosteal releasing of the deep medial collateral off the tibia in the varus knee and releasing the lateral side of the knee by pie crusting with an 18-gauge needle the iliotibial band and lateral collateral with the goal of symmetrical collateral tension.

The "POLO" (Pull-Out, Lift-Off) test as described by Scott and Chmell [6] was used to assess PCL balance. Posterior-cruciate ligament balance was deemed optimal when, with the knee at 90° of flexion, there was some rollback present, but with no tibial lift-off, and the insert could not be easily pulled out of the flexion gap. The flat insert was usually tried first and if too loose, the lipped insert was tried to tighten the flexion gap. If the PCL was too tight with the flat insert, then the PCL was released off the back of the tibia per the surgeon's preference, and the inserts were tried again. Often after releasing the PCL, the lipped insert was chosen. A looser flexion gap was considered preferable to an overly tight gap. Preliminary gap balancing was done with component trialing, but definitive balancing followed cementation which can change gap dimensions. If satisfactory PCL balance could not be attained, then a PCL substituting design was used.

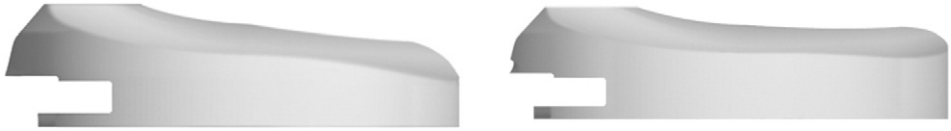

Fig. 1. Comparison between flat insert with 3° of posterior slope (left) and posterior lipped insert, with an additional 4 mm of polyethylene on the posterior part of the insert (right).