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Total Knee Arthroplasty With Preservation of the Posterior Cruciate Ligament

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Abstract: Management of the posterior cruciate ligament (PCL) remains one of the most debated controversies in total knee arthroplasty. Most knee surgeons using fixed-bearing designs fall into one of four camps. Some surgeons preserve the PCL if at all possible. Many others selectively preserve the PCL. Surgeons who sacrifice the PCL rely on excellent flexion-extension balance and sagittally conforming tibial polyethylene inserts for stability. Surgeons who advocate PCL substitution excise and substitute for the ligament using a posterior-stabilized prosthetic design.

Despite the controversy, excellent clinical results have been reported at greater than ten-year follow-up for total knee arthroplasty using all of the techniques described above. Clinical results appear to be associated more with surgical technique and specific prosthetic design than with whether or not the PCL was preserved. Both PCL-preserving designs with a well-balanced PCL and PCL-substituting designs do appear to provide better range of motion and stair-climbing ability than PCL-sacrificing designs.

Management of the Posterior Cruciate Ligament During Total Knee Arthroplasty

The decision to save, sacrifice, or substitute for the posterior cruciate ligament (PCL) during total knee replacement continues to be debated among knee surgeons with strong advocates for each. Excellent results at greater than 10 year follow up have been achieved using all of the techniques described above [5,6,10,19,23,26,27,29,33]. The discussion focuses primarily on comparing total knee arthroplasty with PCL preservation versus PCL substitution, as these are the most common techniques in use. These concepts refer to fixed-bearing total knee arthroplasty and cannot be extrapolated to meniscal-bearing or rotating platform designs.

Preservation of the PCL has several advantages when compared with substitution. Posterior cruciate substitution with a posterior-stabilized prosthesis requires removal of intercondylar bone for the cam and post mechanism. As a consequence, there is increased bone removal compared with PCL preservation (Fig. 1). Removal of intercondylar bone and impaction of the posterior-stabilized femoral component may predispose to iatrogenic intercondylar femur fracture. Resection of the PCL results in an increase in the flexion gap relative to the extension gap [24]. Therefore, for optimal flexion-extension balance, there is a relative increase in distal femoral resection, as well as potential elevation of the joint line.

There are also recognized disadvantages of posterior cruciate preservation. The surgical technique for PCL retention during total knee arthroplasty is less forgiving than for PCL substitution. Preservation of the joint line is more critical. In addition to the balancing of flexion and extension gaps and collateral ligaments, balancing of the PCL is required. In some patients, the PCL may be absent or incompetent and late sagittal instability has been reported following PCL-retaining total knee arthroplasty [17,22].

Early advocates of PCL retention proposed that retaining the PCL would result in increased femoral rollback, better knee stability, decreased stress at the bone-cement-prosthesis interface, and decreased wear [1,33,34]. Increased rollback was hypothesized to result in increased range of motion, more normal knee kinematics, and an increased mechanical advantage of the quadriceps, thereby reducing loads at the patellofemoral joint in flexion [1,34]. We will discuss these arguments in detail below.

As noted above, retention of the PCL is thought to increase femoral rollback and thus increase knee range of motion. PCL-preserving total knee designs do appear to provide improved range of motion and stair-climbing function when compared with posterior cruciate-sacrificing designs [1,46]. However, several recent studies [12,31,43,45] do not demonstrate any advantage when compared with posterior-stabilized prostheses.

Knee kinematics, including femoral rollback, medial and lateral compartment contact points, and axial rotation, have been evaluated both in the laboratory and in vivo with PCL-retaining and PCL-substituting knees [3,7,38,40]. The results have been variable. It is generally accepted that cruciate substitution provides more consistent results and that the results following cruciate preservation are more variable. PCL preservation has been shown to facilitate femoral rollback following total knee arthroplasty in some cases [3,38]. However, other studies refute this finding.

In an in vivo study, Dennis et al. [7] evaluated the influence of total knee arthroplasty design on knee kinematics during deep knee bends under fluoroscopic surveillance. They compared the findings from normal controls and patients with torn anterior cruciate ligaments(ACL) to patients with a PFC posterior cruciate-retaining or substituting pros-

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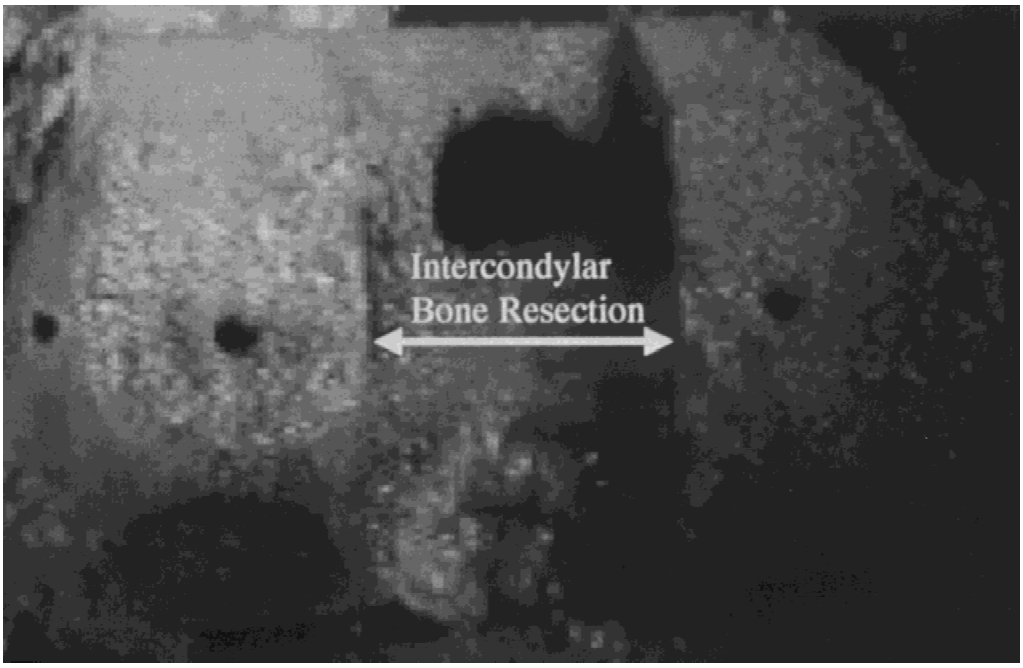

Fig. 1. Example of intercondylar bone resection necessary to accommodate femoral cam with a posterior-stabilized knee design.

thesis (Johnson & Johnson, Stamford, CT). In their study, normal knees started anteriorly and consistently rolled back approximately 14 mm with flexion. Posterior-stabilized knees started centrally and consistently rolled back approximately 8 mm with flexion. Both ACL-deficient native knees and PCL-retaining total knee arthroplasties had inconsistent patterns, with most starting more posterior and many actually sliding anterior during flexion. The authors concluded that posterior-stabilized designs more closely and consistently replicated normal knee kinematics. Moreover, they hypothesized that the anterior sliding seen with posterior cruciate-retaining total knees may lead to increased polyethylene wear which has been noted with some PCL-retaining designs. However, this study has limitations that must be taken into consideration. Knee kinematics were assessed during an atypical activity. Despite the fact that a three-dimensional computer library was developed to analyze out of plane rotations, the accuracy of this technique was not documented and the results with regard to rotational differences were not reported. Additionally, there is no objective method to determine whether the technical job of balancing the PCL was optimal in these patients. Even if the findings are accurate, a surgeon must recognize that these findings relate specifically to the prosthetic designs used in this study. These findings should not be extrapolated to other cruciate-retaining prostheses and posterior-stabilized designs with different geometries and locations of the cam and peg. Stiehl et al. [40] noted similar findings in cruciate-preserving designs in a similar in vivo fluoroscopic study.

In another in vivo fluoroscopic study evaluating knee kinematics, Banks et al. [3] found contradictory results. The authors compared kinematics in patients following total knee replacement using the 7000 Series (Osteonics, Allendale, NJ) and the AMK (Depuy, Warsaw, IN) posterior cruciate-preserving designs to patients undergoing total knee arthroplasty using the Primary Posterior Stabilized Total Knee (Osteonics). Patients with the AMK design had retention of the PCL with a bone block maintained anterior to the ligament. Patients with the 7000 Series Knee had recession of the PCL without a bone block. The authors found that patients with the AMK design (cruciate-retaining with a bone block) demonstrated more normal kinematics with regard to both rotation and translation than patients with the 7000 Series or Primary Posterior Stabilized designs. They concluded that both surgical technique and component design could alter knee kinematics. An advantage of this study is that the accuracy of the technique was calibrated with regard to both rotation and translation. Axial rotational changes were measured and clearly documented. Finally, knee kinematics were evaluated in a step-up activity, which attempts to replicate a normal activity in this patient population. The study did have several limitations, however. Rotation and translation in the prosthetic knees were compared with normal and ACL-deficient knees. However, the kinematics of normal and ACL-deficient native knees were not included in the study for comparison, nor was the direction of translation and rotation clearly described. Moreover, normal and ACL-deficient knees were grouped together and it is not clear whether the AMK group more closely resembled normal knees, ACL-deficient knees or both. There again is no objective tool to account for factors related to surgical technique. The findings utilizing the above posterior-stabilized design may differ from the results had another posterior-stabilized knee been utilized. Obviously, if the location of the peg is extremely anterior, less posterior rollback will occur with flexion compared with a more posteriorly positioned peg assuming otherwise identical geometry.

There is no clear advantage of cruciate-preserving or cruciate-substituting designs with regard to knee kinematics. The inability to objectively assess surgical technique with regard to optimizing function for either preserving or substituting designs is a limitation of all studies attempting to compare these designs.

Increased wear with PCL-preserving total knee arthroplasty compared with PCL substitution or sacrifice has been proposed as a disadvantage of cruciate retention. Early advocates of PCL retention proposed that the PCL would function to control rollback and limit shear forces at the articulating surfaces [33,34]. However, because of concerns regarding a kinematic conflict and decreased motion, most early cruciate-retaining designs had relatively flat tibial polyethylene in the sagittal plane. As a result, they had low conformity with high contact stresses. In addition, many of these designs had flat-on-flat articulating surfaces in the coronal plane with concern for edge loading with varus or valgus stress. From a biomechanical standpoint, high contact stresses and edge loading may lead to higher rates of polyethylene wear. These biomechanical concerns have been supported clinically by increased wear rates and catastrophic polyethylene failures seen with some cruciate-retaining designs (Fig. 2) [9,15,41]. Many current successful PCL-preserving designs utilize tibial polyethylenes that are more sagittally conforming. Although tight PCLs may limit knee flexion in patients with sagittally conforming inserts, excellent knee motion can clearly be obtained with posterior cruciate preservation utilizing these inserts, provided that the PCL is balanced appropriately [35]. Due to changes in design, some of the concerns of increased wear with cruciate retention probably do not apply with the more conforming modern designs with appropriate ligament balancing and adequate polyethylene thickness.

The role of preserving the PCL on knee stability is another area of controversy. Posterior dislocations of the knee have been reported with cruciate-substituting designs and remain a concern (Fig. 3) [18,37]. On the other hand, late posterior instability has been reported following cruciate-preserving total knee arthroplasty [9,22,44]. This has been reported more frequently in patellectomized patients and in patients with rheumatoid arthritis [17,25]. Therefore, both cruciate preservation and substitution are at risk for sagittal instability.

Patellofemoral pain and patellar clunk syndrome have been reported with fairly high rates using certain posterior-stabilized designs [36,39]. Patellofemoral complications have also been associated with at least one cruciate-retaining design [42]. These complications are more likely related to design and surgical technique than to whether or not the cruciate ligament was preserved.

Surgical Decision Making During Total Knee Arthroplasty With Posterior Cruciate Ligament Preservation

PCL preservation during total knee arthroplasty is more demanding both technically and with regard to surgical decision making than routine PCL substitution. Some surgeons will attempt to preserve the PCL if at all possible, whereas other surgeons prefer preservation in only selected cases with less deformity and low risk for late instability.

Patients with severe deformity and rheumatoid arthritis who undergo cruciate-retaining total knee arthroplasty may

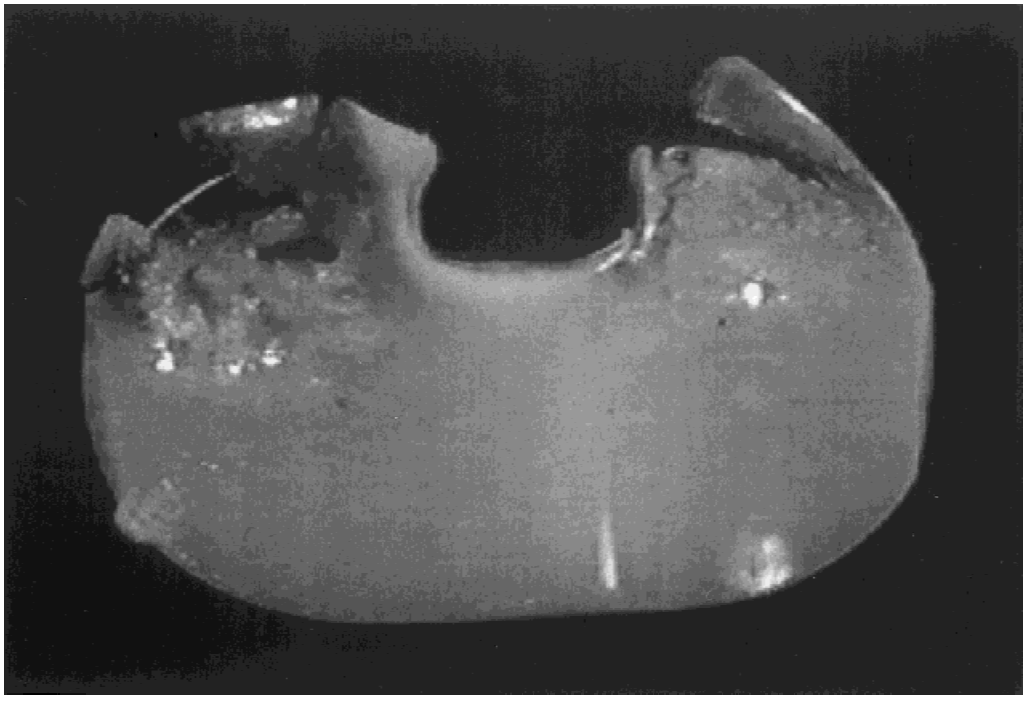

Fig. 2. Example of polyethylene insert from a cruciate-retaining knee design with catastrophic wear.

have poorer results when compared with posterior-stabilized designs [16,17]. One series [17] in rheumatoid patients showed better knee scores and survivorship with a posterior-stabilized design. The cruciate-retaining knees also tended to develop late sagittal instability in this series. Higher failure rates have also been documented following cruciate-retaining total knee arthroplasty in patients with significant fixed varus deformity. Posterior-stabilized knees were again associated with better results [16]. However, other authors [8,14,30,32] have reported excellent results with PCL preservation in these patient populations. The findings noted in the above series may be secondary to either surgical technique or the specific prosthetic designs utilized.

Patellectomized patients have poorer results following total knee replacement with cruciate retention, sacrifice, or substitution when compared with nonpatellectomized patients [20]. However, the results do appear to be somewhat better with posterior-stabilized designs in these patients [4,20,25]. In one study [25], patients with cruciate-retaining knees and prior patellectomy had lower knee scores and higher rates of sagittal instability compared with patients with a posterior-stabilized prosthesis.

Because of these issues, many surgeons will selectively preserve the PCL and substitute for the ligament in some or all of the conditions noted above. A posterior-stabilized knee should probably be utilized for patients with prior patellectomy. Only experienced knee surgeons should consider use of a posterior cruciate-preserving prosthesis for patients with significant deformity. Obtaining excellent flexion-extension balance without notable elevation of the joint line is critical in the setting of significant deformity if a cruciate-retaining prosthesis is to be used. Given the excellent results with posterior-stabilized designs, substitution is advisable for most surgeons. PCL preservation in the setting of rheumatoid arthritis can be accomplished provided that the ligament is intact, a fairly sagittally conforming polyethylene insert is utilized, and excellent flexion-extension balance is obtained [11]. Even if late rupture occurs, good function can be expected as has been seen with earlier posterior-sacrificing designs [30].

Fig. 3. Example showing posterior dislocation of the knee with a cruciate-substituting design.

Several techniques have been adopted for proper balancing of the PCL with recession. The POLO (push-out, lift-off) test assumes use of a sagittally curved tibial tray trial without a stem [35]. Anterior lift-off demonstrates excessive PCL tightness and need for recession [28,35]. The ability to pull out the sagittally curved tibial component from the articulating femoral component in flexion indicates a loose flexion space. This can be managed with a thicker tibial polyethylene, provided that flexion-extension balance can be obtained without notable joint line elevation. A second criterion described to evaluate PCL balance is measuring PCL deflection in 90 degrees of flexion with firm digital pressure. The PCL should not be "bowstring tight" and should not allow more than 1–2 mm deflection according to the advocates of this technique. Surgeons using these techniques to balance the PCL report improved motion compared with earlier cruciate-retaining series. No increase in late instability has been noted in patients undergoing PCL recession [2,28,35]. If satisfactory soft tissue balance cannot be obtained, one should consider conversion to a posterior-stabilized design.

In summary, there are arguments for both PCL preservation and substitution during total knee arthroplasty. Preservation of the ligament is more technically demanding than substitution as the flexion-extension balancing is less forgiving and the PCL must be balanced as well. However, total knee arthroplasty with cruciate-retaining designs allows decreased femoral bone resection relative to substitution using currently available posterior-stabilized designs. There is probably a decreased likelihood of iatrogenic intercondylar fracture with cruciate retention. PCL preservation facilitates anatomic restoration of the joint line because resection of the PCL increases the flexion gap, requiring more distal femoral resection for optimal flexion and extension balance. Therefore, total knee arthroplasty with preservation of the PCL may be preferable to substitution in properly selected patients.

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