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Posterior Stabilized Total Knee Arthroplasty

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1. Introduction

The posterior cruciate ligament (PCL) in total knee arthroplasty (TKA) functions to prevent posterior translation of the tibia and aids in femoral roll-back¹. Roll-back allows for increased quadriceps lever arm and more efficient use of extensor musculature, permitting more normal stair climbing. Because of this, PCL retaining knees have the advantage of maintenance of ligamentous proprioception, load transfer by the native PCL and anterior-posterior stability. However, retaining the PCL also has several disadvantages. Surgical exposure of the tibia, gap balancing and reliance on diseased ligament morphology make consistent TKA results difficult. The posterior stabilized design in TKA was introduced in the mid-1970s. Surgeons who use this system believed that the results obtained are more consistent because they do not have to rely on abnormal PCL morphology. Consequently, exposure, joint line restoration and appropriate balancing of the knee are easier with PCL stabilized designs. These components are a popular treatment for patients requiring primary TKA. Improvements in implant design, a technically easier procedure in the face of deformity, restoration of knee kinematics and reported very good long-term outcomes may all be reasons for the increased use of this design.

2. History and design rationale

Most of the current total knee implants were derived from the Total Condylar Prosthesis (TCP; Zimmer, Warsaw, Indiana, USA), which was introduced in 1974. This prosthesis was a cruciate sacrificing cemented design. Technique of implantation of the TCP requires excision of the PCL but without substitution. Stability in this implant design was achieved by soft tissue balance in flexion and extension and articular conformity in the coronal and sagittal plane². Consequently, the success of this implant was highly dependent of surgical technique. In 1978, the TCP was modified to the Insall Burstein Posterior Stabilized Prosthesis (IB I) to address posterior subluxation of the tibia and instability. The IB I is the

¹ Dorr LD Ochsner JL, Gronley J, Perry J. Functional comparison of posterior cruciate-retained versus cruciate-sacrificed total knee arthroplasty. CORR 1988; 236:36-43.

² Scuderi GR, Pagnano MR: Review Article: The rationale for posterior cruciate substituting total knee arthroplasty. J Orthopedic Surgery 2001, 9(2):81-88

first posterior stabilized/substituting TKA design. It incorporated a femoral cam that articulates with a polyethylene tibial post to act as a substitute for the excised native PCL. Most posterior stabilized knee designs evolved from the IB I - incorporating a cam-post mechanism to aid in roll back, increase the amount of distraction tolerated before subluxation occurs, and increase varus-valgus constraint. The cam-post mechanism improves both anterior-posterior and translational stability. Multiple studies have shown that function of the TKA is improved with PCL substitution. PCL substitution allowed for better stability, increased ROM, reduced quadriceps force in extension, improved stair-climbing ability, and improved patellofemoral function.^{3 4 5}

3. Advantages of posterior stabilized TKA

There are several advantages with use of posterior stabilized TKA designs. These include: I) easier surgical exposure and ligament balancing, II) predictable restoration of knee kinematics, III) improved range of motion, IV) less polyethylene wear, and V) avoiding the possibility of PCL rupture.

3.1 Easier surgical exposure and ligament balancing

Adequate exposure of the tibia may not be possible with PCL retention. Excision of the PCL aids in exposing the tibia for adequate visualization by releasing the tethering effect of a tight contracted PCL. Moreover, the PCL can be excised from the femoral and tibial attachment in a reproducible way, making the ligamentous balancing and correction of the deformity easier since it is not complicated by the tethering effect of the PCL. Abnormal PCL morphology is often encountered in the diseased knee making predictable gap balancing difficult in PCL retaining designs. If the patient has a "tight", contracted PCL, the knee may be relatively tight in flexion with excessive femoral roll-back. On the other hand, if the PCL is lax or incompetent, the knee may experience posterior sag with no roll-back with knee flexion. Thus, use of posterior stabilized TKA makes balancing more predictable eliminating the reliance on abnormal PCL morphology and function.

3.2 Predictable restoration of knee kinematics

In posterior stabilized TKA, the tibial post articulates with the transverse femoral cam predictably with knee flexion, preventing posterior subluxation of the tibia while maintaining femoral roll back. Many studies report more normal kinematics with the use of posterior stabilized designs.^{6 7 8} Fluoroscopic kinematics showed that the posterior

³ Insall JN, Lachiewicz PF, Burstein AH. The posterior stabilized condylar prosthesis: a modification of the total condylar design. *J Bone Joint Surg Am.* 1982;64:1317

⁴ Scott WN, Rubinstein M, Scuderi G. Results after knee replacement with a posterior cruciate-substituting prosthesis. *J Bone Joint Surg Am.* 1998;70:1163

⁵ Scuderi GR, Insall JN. The posterior stabilized knee prosthesis. *Orthop Clin North Am.* 1989;20:71

⁶ Stiehl JB, Komistek RD, Dennis DA, et al. Fluoroscopic analysis of kinematics after posterior cruciate retaining knee arthroplasty. *J Bone Joint Surg Br* 1995; 77B:884-889.

⁷ Dennis DA, Komistek RD, Hoff WA. In vivo knee kinematics derived using an inverse perspective technique. *Clin Orthop* 1996; 331:107-117.

⁸ Ranawat CS, Komistek RD, Rodriguez JA, et al. In vivo kinematics for fixed and mobile-bearing posterior stabilized knee prostheses. *Clin Orthop Relat Res* 2004; 418:184-190.

stabilized TKA experienced AP femoro-tibial translation more similar to the normal knee during normal gait and deep knee bend.⁹ Moreover, studies have shown no significant difference between posterior stabilized TKA and normal knees with regard to spatio-temporal gait parameters, knee range of motion during stair climbing or in isokinetic muscle strength.¹⁰

A study comparing cruciate retaining, cruciate sacrificing and posterior stabilized TKA found that posterior stabilized designs produced more roll back and better quadriceps efficiency than cruciate retaining knee designs¹¹. Posterior stabilized TKA predictably restores more normal knee kinematics when compared to either PCL substituting or PCL sacrificing designs.

3.3 Improved range of motion

Both cruciate retaining and posterior stabilized TKA designs can provide excellent range of motion. However, range of motion may be better when a posterior stabilized TKA is used to maintain femoral roll back. It appears, according to most comparative studies, that posterior stabilized designs may provide more predictable motion, with greater flexion under fluoroscopic visualization.^{12 13} In a very well done meta-analysis Jacobs *et al.* analyzed eight randomized controlled trials comparing posterior stabilized with cruciate retaining TKA and found that the range of motion was 8° higher (105 versus 113°) in the posterior stabilized group than the cruciate retaining group ($P = 0.01$, 95% confidence interval 1.7-15).¹⁴

3.4 Less polyethylene wear

Retention of the PCL requires that the prosthetic kinematics closely match that of the normal knee. This obligates the implant to have a “flat” polyethylene component relative to the radius of curvature of the femur. This “round on flat” design allows for minimal constraint on tibial component enabling roll back of the femur on tibia with knee flexion. This less conforming design can lead to excessive point contact pressure and increase polyethylene wear. In contrast, in posterior-stabilized design, it is possible to use more conforming polyethylene articulation with minimal point contact stress. Increasing the conformity of the implant, increases the contact area, and decreases the stress to which the polyethylene is subjected. This can potentially minimize polyethylene wear and increase the long-term survival of the TKA. Cases of severe polyethylene wear in cruciate retaining implants with less conforming

⁹ Udomkiat P, Meng BJ, Dorr LD, Wan Z. Clin Orthop 2000 Sep;(378):192-201

¹⁰ Wilson SA, McCann PD, Gotlin RS, Ramakrishnan HK, Wootten ME and Insall JN. Comprehensive gait analysis in posterior stabilized knee arthroplasty. J Arthroplasty 1996, 11:359-67.

¹¹ Mahoney OM, Noble PC, Rhoads DD, Alexander JW, Tullos HS. Posterior cruciate function following total knee arthroplasty: A biomechanical study. J Arthroplasty 1994, 9:569-78.

¹² Jacobs WC, Clement DJ, Wymenga AB. Retention versus removal of the posterior cruciate ligament in total knee replacement: a systematic literature review within the Cochrane framework. Acta Orthop 2005; 76:757-768.

¹³ Maruyama S, Yoshiya S, Matsui N, Kuroda R, Kurosaka M. Functional comparison of posterior cruciate retaining versus posterior stabilized total knee arthroplasty. J Arthroplasty 2004; 19:349-353.

¹⁴ Jacobs WC, Clement DJ, Wymenga AB. Retention versus removal of the posterior cruciate ligament in total knee replacement: a systematic literature review within the Cochrane framework. Acta Orthop 2005; 76:757-768.

tibial inserts have been reported.^{15 16} Additionally, technical issues may contribute to wear in cruciate retaining TKA if the PCL is left too tight in flexion. This can lead to asymmetric posterior polyethylene wear from posterior femoral subluxation and may predispose to osteolysis.

3.5 Avoiding the possibility of posterior cruciate ligament rupture

The PCL can rupture postoperatively with the use of cruciate retaining TKA. This can occur by trauma or inflammatory disease process. Late flexion instability can occur if the PCL fails over time. This complication can also occur iatrogenically when the PCL is overzealously recessed intraoperatively or excessive proximal tibial resection is performed. When too much proximal tibia is resected, the PCL insertion site can be jeopardized. The PCL can also be damaged by synovitis from inflammatory arthropathy, resulting in failure.¹⁷ Thus, avoiding the use PCL retaining implants can eliminate failure and instability by avoiding reliance on the integrity of the native PCL.

4. Disadvantages of posterior stabilized TKA

There are several disadvantages with use of posterior stabilized TKA designs. These include: I) tibial post wear and breakage, II) excessive bone resection, III) patellar clunk syndrome, and IV) tibio-femoral dislocations.

4.1 Tibial post wear and breakage

A potential problem with posterior stabilized design is tibial post polyethylene wear from the cam-post articulation. Excessive wear particulate debris can lead to osteolysis. In a wear analysis of retrieved posterior stabilized TKA components, evidence of wear or damage was observed on all specimens of stabilizing posts, including those revised because of infection.¹⁸ Wear caused premature failure and early revision. Moreover, wear can lead to catastrophic failure of the tibial post through fracture. The authors concluded that the cam-post articulation in posterior stabilized implants can be an additional source of polyethylene wear debris. The variability in wear patterns observed among designs may be due to differences in cam-post mechanics, post location, and post geometry.¹⁹

4.2 Excessive bone resection

It is necessary to remove bone from the intercondylar notch in order to accommodate the tibial post in most posterior stabilized TKA designs. This obligatory "box" cut can be significant in smaller sized femurs especially in TKA systems where the post remains a

¹⁵ Collier JP, Mayor MB, McNamara JL, et al. Analysis of the failure of 122 polyethylene inserts from uncemented tibial knee components. *Clin Orthop Relat Res* 1991; 273:232-242.

¹⁶ Kilgus DJ, Moreland JR, Finerman GA, et al. Catastrophic wear of tibial polyethylene inserts. *Clin Orthop Relat Res* 1991; 273:223-231.

¹⁷ Waslewski GL, Marson BM, Benjamin JB. Early, incapacitating instability of posterior cruciate ligament-retaining total knee arthroplasty. *J Arthroplasty* 1998; 13:763-767.

¹⁸ Puloski SK, McCalden RW, MacDonald SJ, et al. Tibial post wear in posterior stabilized total knee arthroplasty. An unrecognized source of polyethylene debris. *J Bone Joint Surg Am* 2001; 83A:390-397.

¹⁹ Dolan MM, Kelly NH, Nguyen JT, Wright TM, Haas SB. Implant design influences tibial post wear damage in posterior-stabilized knees. *Clin Orthop Relat Res*. 2011 Jan;469(1):160-7.

constant size for each femoral component size.²⁰ The consequence is that there will be a relatively large notch cut for a small femoral component greatly weakening the condyle and increasing the risk of femoral condyle bone loss and periprosthetic fracture. Surgeons who chose to use posterior stabilized TKA should familiarize themselves with relative “box” cut volume to avoid intra-operative and post-operative periprosthetic fractures, especially in small, osteoporotic femurs.

4.3 Patellar clunk

Patella clunk is a complication that is more prevalent in posterior stabilized TKA designs. A prominent fibrous nodule can form at the junction of the proximal patellar pole and the quadriceps tendon. During deep flexion, this fibrous nodule can “catch” in the intercondylar notch of the femoral component causing a catching sensation on the end of the groove as the patella moves back with knee extension. It is this catching and then forceful release with extension that results in the “clunk” and pain characteristic of this condition.²¹ Recommended treatment consists of physical therapy and arthroscopic debridement. Arthrotomy and possible revision surgery is reserved for recurrent clunks, malposition or loose components.²²

4.4 Tibio-femoral dislocations

One of the disadvantages of posterior stabilized TKA is the potential for dislocation in flexion as the tibial post rides underneath the femoral cam. This occurs when there is significant extension-flexion gap mismatch. More specifically, dislocations occur when the flexion gap is larger than the corresponding extension gap, allowing the post to “jump” over the cam. The incidence of dislocation with posterior stabilized TKA is very rare with modern designs (0.2%).²³ To prevent knee dislocation it is mandatory that the surgeon balance the knee both in flexion and extension. When dislocation occurs, closed and sometimes open reduction is required. If recurrent dislocation occurs, revision surgery to correct flexion extension mismatch is imperative.

5. Alternative to cam post design

The “deep-dish” tibial insert, introduced by Hoffman et al in 2000, is an alternative to the cam post posterior stabilized TKA design. This type of design eliminated the need for resection of the intercondylar notch bone stock and use of a tibial post. AP stability is achieved by using highly conforming tibial inserts with anterior build-up²⁴. Some advantages of this ultra-congruent design include: bone preservation by eliminating the

²⁰ Haas S, Nelson C, Laskin R. Posterior stabilized TKA: an assessment of bone resection. *The Knee* 2000; 7: 25-29.

²¹ Hozack WJ, Rothman RH, Booth RE Jr, Balderston RA. The patellar clunk syndrome. A complication of posterior stabilized total knee arthroplasty. *Clin Orthop Relat Res* 1989; 241:203-208.

²² Beight JL, Yao B, Hozack WJ, et al. The patellar 'clunk' syndrome after posterior stabilized total knee arthroplasty. *Clin Orthop Relat Res* 1994; 299:139-142.

²³ Lombardi AV Jr, Mallory TH, Vaughn BK, et al. Dislocation following primary posterior-stabilized total knee arthroplasty. *J Arthroplasty* 1993; 8:633-639.

²⁴ Hofmann AA, Tkach TK, Evanich CJ, Camargo MP: Posterior stabilization in total knee arthroplasty with use of an ultracongruent polyethylene insert. *J Arthroplasty* 2000;15:576-583

need for box cut, elimination of post breakage and wear, elimination of tibio-femoral dislocation and patella clunk syndrome. In addition, the ultracongruent tibial component has the advantage of distributing the loads over a larger surface area of the polyethylene insert, hypothetically limiting and distributing more evenly the loads at the bone–implant interface. Moreover, because femoral box preparation is eliminated, femoral bone stock is preserved, decreasing the potential for fracture and operative time.²⁵ Several studies comparing the stability, range of motion and stair climbing ability found no significant difference with ultracongruent design TKA when compared to traditional cam post design TKA.

6. Outcomes

Despite the dissimilarities between cruciate retaining and posterior stabilized TKA designs, most comparative studies have found no significant differences in function, patient satisfaction, or survivorship of the two designs in unselected patient cohorts.²⁶ We have divided the reported results after posterior stabilized TKA into specific outcomes to facilitate the review. Specific outcomes include the performance of posterior stabilized TKA designs in terms of proprioception, wear, loosening, and stability. Also the results with the use of posterior stabilized TKA in two particular subgroups of patients: varus-flexion deformity and postpatellectomy are included in this section.

7. Proprioception

Proprioception after TKA may be improved with the preservation of the native PCL. Mechanoreceptors have been identified in the native posterior cruciate ligament may aid in feedback mechanism improving proprioception.²⁷ Hystological analysis, however, suggests that marked neurologic degeneration occurs within the posterior cruciate ligament as part of the arthritic process [13]. Clinical studies are not conclusive as to which implant design has better proprioception. Warren *et al.* [14] observed that proprioception improved after TKA with either a posterior stabilized or cruciate retaining design, but suggested that greater improvement occurred in the cruciate retaining group. In contrast, Simmons *et al.* [15] noted that in patients with severe arthritis better postoperative proprioception was obtained with a posterior stabilized TKA. Becker *et al.* [16] compared patients with bilateral paired cruciate retaining and posterior stabilized TKA. Fifty percent of the patients were unable to express a preference for one knee or the other. The other 50% were equally divided between those who preferred the cruciate retaining and those who preferred the posterior stabilized knee. Most recently Swanik *et al.* [17] performed a prospective, randomized study on 20 patients to assess proprioception, kinesthesia, and balance following TKA comparing posterior stabilized

²⁵ Laskin RS, Maruyama Y, Villaneuva M, Bourne R. Deep-dish congruent tibial component use in total knee arthroplasty: a randomized prospective study. *Clin Orthop Relat Res.* 200 Nov;(380):36-44.

²⁶ Jacobs WC, Clement DJ, Wymenga AB. Retention versus removal of the posterior cruciate ligament in total knee replacement: a systematic literature review within the Cochrane framework. *Acta Orthop* 2005; 76:757-768.

²⁷ Warren PJ, Olanlokun TK, Cobb AG, Bentley G. Proprioception after knee arthroplasty: the influence of prosthetic design. *Clin Orthop Relat Res.* 1993;297:182-187.

versus cruciate retaining designs. Joint position sense, the threshold to detect joint motion, and the patient's ability to balance on an unstable platform were assessed prior to and at least 6 months after the operation. They found that after TKA all patients detected motion significantly faster, reproduced joint position with less error and had balance improvement. The group treated with the posterior stabilized TKA more accurately reproduced joint position when the knee was extended from a flexed position. The authors conclude that retention of the PCL does not appear to improve proprioception and balance.

7.1 Loosening

At long-term follow-up there appears to be no significant difference in the aseptic loosening rates of posterior stabilized and cruciate retaining TKA designs. The cemented posterior stabilized TKA has a reported 98.1% survival rate at 14 years [19]. In the most recent study Rasquinha *et al.* [20••] reported the long-term results of a series of 150 consecutive posterior stabilized TKA that were performed in 118 patients. They found a good to excellent result in 90% of patients at mean follow-up of 12 years. At 12 years, the survival rate was $94.6 \pm 4.0\%$ with failure for any reason as the end point and $98.3 \pm 2.4\%$ with mechanical failure as the end point. Revision surgery was necessary in five cases: two because of infection, one for dislocation and two for polyethylene wear and osteolysis.

7.2 Stability

As mentioned above with posterior stabilized TKA if the knee is not properly balanced dislocation in flexion can occur. This is a very rare event, and can be avoided with careful balancing of the flexion and extension gaps. In terms of instability, posterior or flexion instability may in fact be a greater, although less recognized, problem with cruciate retaining TKA designs. Rupture of the PCL after surgery can cause pain and disability. Flexion instability can also result when the flexion space is left too loose, resulting in marked anterior-posterior translation of the tibia on the femur in flexion. Pagnano *et al.* [21] reported on 25 cruciate retaining TKAs treated for flexion instability. These patients presented with a typical constellation of symptoms that included a sense of knee instability without true give-way, recurrent knee joint effusions, and anterior knee pain. On exam, these knees had obvious anteroposterior instability when tested at 90° of flexion, and even demonstrated a marked posterior sag sign. They all underwent revision surgery to a posterior stabilized design and 22 of the 25 had significant symptomatic improvement after revision surgery.

7.3 Correction of deformity

Most series of patients with varus deformities have shown excellent results after 10-15 years, with either cruciate retaining or posterior stabilized TKA. There is, however, only one comparative study [22] that evaluated the results of cruciate retaining and posterior stabilized implants in the context of severe varus or varus-flexion deformities. In this series, survivorship, range of motion, and pain-related outcomes were worse in patients with fixed varus (or varus-flexion) deformities over 15° who were treated with cruciate retaining devices, compared with patients treated with posterior stabilized implants or with those who did not have such varus deformities and were treated with cruciate retaining devices.

7.4 Postpatellectomy patients

Most authors suggest that a posterior stabilized design is most appropriate in patients with previous patellectomy. The tibial post and femoral cam mechanism limits the posterior translation of the tibia that can occur without the patella. Patellectomy leads to the disruption of the normal kinematics of the knee. In the context of knee replacement, it has been hypothesized that loads on the PCL in the years following surgery may be increased, potentially resulting in late attenuation and instability [23,24]. Patellectomy also can cause decreased extensor mechanism power because of the loss of the fulcrum provided by the intact patella. A retrospective study showed that patellectomized patients treated with posterior stabilized implants had better functional and pain scores than did those treated with cruciate retaining implants [23]. In comparison to cruciate retaining designs, posterior stabilized devices lead to better results when TKA is performed in patients with prior patellectomies [25].

8. Rheumatoid arthritis

Total knee arthroplasty is a proven technique for the management of deformity and unremitting pain in the rheumatoid arthritic knee. Many important considerations must be taken into account in order to maximize the results of total knee replacement in this challenging patient population. In a retrospective study, Laskin et al²⁸ reported that cruciate retaining implants in patients with rheumatoid arthritis were associated with inferior results compared with posterior stabilized implants, principally because of late instability and progressive recurvatum deformity. The tendency for generalized ligamentous laxity and attenuation and joint deformity in these patients make successful TKA difficult with PCL retaining designs. These patients may present with severe or fixed valgus deformities. Most patients with rheumatoid arthritis typically have poor quality of the soft tissues and the potential for synovitis to cause late attenuation and rupture of the PCL.

9. Conclusion

The use of posterior stabilized TKA has several advantages. Potential benefits of a posterior stabilized TKA over a cruciate retaining TKA include easier surgical exposure and ligament balancing, predictable restoration of knee kinematics, improved range of motion, less wear, and avoiding the possibility of PCL rupture. In addition, the use of posterior stabilized TKA appears to be advantageous in correction of severe varus - valgus deformity. A potential problem with posterior stabilized TKA is tibial post polyethylene wear from the cam-post mechanism. Excessive wear can lead not only to osteolysis but also post fracture. Other disadvantage of posterior stabilized TKA is patellar 'clunk' syndrome, risk of dislocation or flexion instability and bone loss and peri-prosthetic condylar fracture. Despite the dissimilarities between cruciate retaining and posterior stabilized TKA designs, most studies have found no significant differences in function, patient satisfaction, or survivorship of the two designs in unselected patient cohorts. Posterior stabilized TKA outcomes appear to be better in a particular subgroup of patients including patients with patellectomy, large varus or varus-flexion deformity, and rheumatoid arthritis.

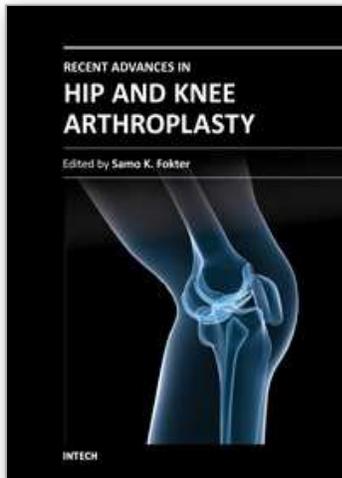
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The purpose of this book is to offer an exhaustive overview of the recent insights into the state-of-the-art in most performed arthroplasties of large joints of lower extremities. The treatment options in degenerative joint disease have evolved very quickly. Many surgical procedures are quite different today than they were only five years ago. In an effort to be comprehensive, this book addresses hip arthroplasty with special emphasis on evolving minimally invasive surgical techniques. Some challenging topics in hip arthroplasty are covered in an additional section. Particular attention is given to different designs of knee endoprotheses and soft tissue balance. Special situations in knee arthroplasty are covered in a special section. Recent advances in computer technology created the possibility for the routine use of navigation in knee arthroplasty and this remarkable success is covered in depth as well. Each chapter includes current philosophies, techniques, and an extensive review of the literature.

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