

Semiconstrained posterior-stabilized total knee arthroplasty: indications, risks and benefits in primary and revision surgery

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Background: The constrained posterior-stabilized (CPS) implant for use in total knee arthroplasty (TKA) has a constraint level midway between that of a posterior-stabilized implant and a valgus–varus–constrained implant; there is currently no consensus on the surgical indications for use of this degree of constraint. We present our experience using this implant at our centre.

Methods: We reviewed the charts of patients who received a CPS polyethylene insert during TKA in our centre between January 2016 and April 2020. We collected patient demographic characteristics, surgical indications, pre- and postoperative radiographs, and complications.

Results: A total of 85 patients (74 females and 11 males with a mean age of 73 yr [standard deviation 9.4 yr, range 36–88 yr]) (85 knees) received a CPS insert over the study period. Of the 85 cases, 80 (94%) were primary TKA and 5 (6%) were revision TKA. The most common indications for primary CPS use were severe valgus deformity with medial soft-tissue laxity (29 patients [34%]), medial soft-tissue laxity without substantial deformity (27 [32%]) and severe varus deformity with lateral soft-tissue laxity (13 [15%]). The indications for the 5 patients who underwent revision TKA were medial laxity (4 patients) and an iatrogenic lateral condyle fracture (1 patient). Four patients had postoperative complications. The 30-day return to hospital rate was 2.3% (owing to infection and hematoma). A single patient required revision surgery for periprosthetic joint infection.

Conclusion: We found excellent short-term survivorship of the CPS polyethylene insert when used for a spectrum of coronal plane ligamentous imbalances with or without preoperative coronal plane deformities. Long-term follow-up of these cases will be important to identify adverse outcomes such as loosening or polyethylene-related problems.

Contexte : La prothèse postéro-stabilisée cimentée en arthroplastie totale du genou (ATG) a un degré de contrainte entre la prothèse postéro-stabilisée et la prothèse semi-contrainte. L'indication chirurgicale de ce degré de contrainte ne fait pas encore consensus. Cet article présente l'expérience de notre centre avec cette prothèse.

Méthodes : Nous avons analysé les dossiers de patients ayant reçu un insert postéro-stabilisé cimenté en polyéthylène au cours d'une ATG dans notre centre entre janvier 2016 et avril 2020. Nous avons recueilli les caractéristiques démographiques, l'indication de l'intervention, les radiographies pré- et postopératoires et les complications.

Résultats : Au total, 85 patients (74 femmes et 11 hommes, âge moyen 73 ans [écart-type 9,4 ans, intervalle 36–88 ans]) ont reçu un insert postéro-stabilisé cimenté pendant la période de l'étude. Il s'agissait d'une ATG de première intention pour 80 (94%) des cas et de reprise pour 5 (6%) d'entre eux. Les indications les plus fréquentes pour la prothèse postéro-stabilisée cimentée de première intention étaient une déformation valgus grave avec laxité ligamentaire interne (29 patients [34%]), une laxité ligamentaire interne sans déformation majeure (27 patients [32%]) et une déformation valgus grave avec laxité ligamentaire externe (13 patients [15%]). Pour les 5 ATG de reprise, les indications étaient une laxité interne (4 patients) et une fracture iatrogène du condyle latéral (1 patient). Des complications postopératoires sont survenues chez 4 patients, avec un taux de retour à l'hôpital dans les 30 jours à 2,3% (pour une infection et un hématome). Un seul patient a nécessité une chirurgie de reprise pour une infection de prothèse articulaire.

Conclusion : Nous avons obtenu une excellente survie prothétique à court terme de l'insert postéro-stabilisé cimenté en polyéthylène utilisé dans toutes sortes de déséquilibres ligamentaires frontaux avec ou sans déformations frontales préopératoires. Il est important de suivre ces cas à long terme pour repérer les effets indésirables tels que le descellement ou des problèmes liés au polyéthylène.

Total knee arthroplasty (TKA) can decrease pain and improve quality of life substantially in patients with knee arthritis.¹ With increasing demand owing to an aging population, the number of TKA procedures performed annually in the United States is expected to increase by 143% by 2050.² Knee stability after TKA is a fundamental factor for successful TKA. Fehring and colleagues³ reported that the reason for revision TKA in their cohort was instability in 27% of patients. Knee stability is obtained in various ways, with a major factor being the constraint level associated with specific implant designs. The level of constraint required depends on many factors, such as ligamentous integrity, severity of knee deformities and quality of the bone stock.

The level of constraint in TKA is defined by the implant design. With the majority of primary TKA procedures, soft-tissue balancing is all that is required to allow the implant to tension symmetrically in flexion and extension, providing satisfactory knee stability. If after soft-tissue balancing acceptable stability is not achieved, the surgeon can resort to using a more constrained implant. This can provide the stability required to counteract the deforming forces applied on the soft-tissue envelope of the knee.⁴ However, the increased constraint amplifies the stress across the implant, which may increase polyethylene wear and can lead to aseptic loosening and implant failure.⁴ Several authors recommend adding stems to the femoral and tibial implants to create a load-sharing device in order to reduce the risk of loosening when increased levels of constraint are used.⁵⁻⁷ Historically, use of the least amount of constraint needed to achieve stability during TKA has been recommended.⁸ This may not always be possible in cases of severe valgus or varus deformities with incompetent ligaments or severe flexion contractures, in which considerable soft-tissue releases are necessary.⁹ The generally accepted spectrum of constraint by TKA design goes from cruciate-retaining (least constraint), posterior-stabilized, condylar-constrained or varus–valgus–constrained (VVC), and hinged (most constraint).¹⁰ In describing the level of

constraint, it is most common to use the descriptive terminology of the implant (e.g., cruciate-retaining, posterior-stabilized) rather than brand name or specific degrees of constraint, since there is little standardization among different brands (Table 1).

The Persona constrained posterior-stabilized (CPS) articular insert (Zimmer Biomet) has a constraint level midway between that of a posterior-stabilized insert and a VVC insert. In the current literature, there are no clear validated indications for the use of a CPS insert. However, there are some manufacturer-proposed indications based on collateral ligament integrity and degree of deformity: marked valgus deformity, prior high tibial osteotomy, patellectomy and certain revision situations for instability.¹¹ To our knowledge, these indications have not yet been validated by independent studies, which leaves the decision to use this semiconstrained design up to the surgeon. According to the manufacturer, the CPS insert was designed to allow 1.5° of varus–valgus motion and 5.5° of internal–external rotation.¹¹ It is also currently unclear whether the surgeon should use stemmed implants when a semiconstrained liner is used to help with load sharing and potentially reduce the risk of loosening. In comparison, the more constrained VVC design from the same manufacturer allows 1.25° of varus–valgus motion and 2° of internal–external rotation. The major advantage of the CPS insert is that it can be used with the same instrumentation and implants as the primary posterior-stabilized TKA design. Therefore, if inadequate intraoperative stability is noted, the surgeon can simply use a CPS polyethylene liner rather than converting to different implants, as with a VVC design.

We present our 5-year experience with the CPS articular insert. We describe the characteristics of our patient cohort, as well as the short-term survivorship of the prosthesis and relevant complications. We aimed to provide insight into surgical indications leading to the use of a semiconstrained-design TKA, benefits and potential pitfalls.

Table 1. Degrees of constraint of common total knee arthroplasty implant designs

Type of prosthesis*	Characteristics	Constraints
Cruciate-retaining	<ul style="list-style-type: none"> • Least amount of constraint restores near-normal knee kinematics • Requires good bone, and intact collateral ligaments and PCL 	<ul style="list-style-type: none"> • 15° internal–external rotation
Posterior-stabilized	<ul style="list-style-type: none"> • Sacrifices PCL • Bigger polyethylene cam and femoral notch relative to posterior-stabilized • Limited valgus–varus and rotation stability 	<ul style="list-style-type: none"> • No varus–valgus constraint • 15° internal–external rotation
Constrained posterior-stabilized	<ul style="list-style-type: none"> • Used only with removed PCL • Varus–valgus stability, moderate rotation constraint 	<ul style="list-style-type: none"> • 1.5° varus–valgus constraint • 5.5° internal–external rotation
Varus–valgus–constrained or condylar-constrained nonhinged knee	<ul style="list-style-type: none"> • Semiconstrained, nonlinked implant • Varus–valgus stability, rotational stability 	<ul style="list-style-type: none"> • 1.25° varus–valgus constraint • 2° internal–external rotation
Constrained hinged knee	<ul style="list-style-type: none"> • Highest degree of constraint 	<ul style="list-style-type: none"> • No varus–valgus movement

PCL = posterior cruciate ligament.
 *From least constrained to most constrained.

METHODS

After obtaining ethics approval for this retrospective review, we included all patients who underwent primary or revision TKA surgery with a CPS articular insert between January 2016 and April 2020 at our hospital and were followed for at least 1 year. The procedures were performed by 6 fellowship-trained orthopedic surgeons. The decision to increase the degree of constraint was based on the surgeon's expertise in correlating preoperative and intraoperative findings.

We conducted a chart review from electronic and paper patient records at our hospital. We collected patient demographic information including age, sex, weight and American Society of Anesthesiologists score. We also collected data from operative reports, including preoperative diagnosis, surgical indication, tourniquet time, size and type of implant, and whether a stemmed component was used. In addition, intraoperative complications and any concomitant procedures were documented. Subsequently, we reviewed the pre- and postoperative radiographs to quantify the severity of degenerative changes (graded according to the Kellgren–Lawrence classification¹²) and alignment of the knee. Indicators of soft-tissue laxity (joint space opening or knee subluxation) and the hip–knee–ankle angle were measured to quantify the alignment of the lower extremity in the coronal plane. Finally, we documented 30-day return to the emergency department, readmission or need for revision surgery. We reviewed the last available follow-up radiographs to identify any implants at risk for failure (implant migration, severe osteolysis or other signs of loosening) and any planned revision surgery.

Statistical analysis

We described patient demographic characteristics with arithmetic mean, and reported all errors were as standard deviations (SDs). We determined the ratio of CPS inserts to less-constrained designs (cruciate-retaining or posterior-stabilized) by comparing the total number of TKA procedures performed over the study period. We reported preoperative alignment of the knee in degrees and classified it as varus (positive numbers) or valgus (negative numbers), with associated means and SDs.

RESULTS

Between Jan. 1, 2016, and Apr. 1, 2020, 85 patients (74 females and 11 males with a mean age of 73 yr [standard deviation (SD) 9.4 yr, range 36–88 yr]) (85 knees) received a CPS polyethylene insert during TKA (Table 2). Of the 85 procedures, 80 (94%) were primary surgery and 5 (6%) were revision surgery. The surgery was performed through a medial parapatellar approach in all cases. The

Table 2. Characteristics of 85 patients who received a constrained posterior-stabilized bearing during total knee arthroplasty

Characteristic	Mean \pm SD* (range)
Age, yr	73 \pm 9.4 (36 to 88)
Female sex, no. (%) of patients	74 (87)
Body mass index	29.6 \pm 5.6 (18.0 to 44.4)
ASA score	2.2 (1 to 3)
Kellgren–Lawrence score	3.9 (3 to 4)
Valgus preoperative alignment	14.4 \pm 6.1 (1 to 31)
Varus preoperative alignment	-13.6 \pm 7.2 (-2 to -27)

ASA = American Society of Anesthesiologists; SD = standard deviation.
*Except where noted otherwise.

Table 3. Surgical indications for use of the Zimmer Biomet constrained posterior-stabilized polyethylene liner

Indication	No. (%) of patients <i>n</i> = 85
Severe valgus with MCL laxity	29 (34)
MCL laxity	27 (32)
MCL injury	4 (5)
Severe varus with LCL laxity	13 (15)
Valgus contracture	1 (1)
LCL laxity	2 (2)
Lateral bone defect	1 (1)
Global instability	1 (1)
Intraoperative lateral condyle fracture	1 (1)
Revision for medial laxity	4 (5)
Medial bone defect	2 (2)

LCL = lateral collateral ligament; MCL = medial collateral ligament.

thickness of the CPS polyethylene inserts ranged from 10 mm to 18 mm (mean 13.1 mm, median 14 mm). All implants were cemented, and short stems (14 mm \times 30 mm) were used on the tibia in 54 cases (63%). In all, 1760 primary TKA procedures were performed at our centre over the study period, meaning that 4.5% of knees received a semiconstrained-design implant.

The preoperative diagnosis was osteoarthritis in 79 patients (93%), posttraumatic osteoarthritis in 1 patient (1%) and revision in 5 patients (6%). The most common indications for primary CPS use were severe valgus deformity with medial soft-tissue laxity (29 patients [34%]), medial soft-tissue laxity without major deformities (27 patients [32%]) and severe varus deformity with lateral soft-tissue laxity (13 patients [15%]) (Table 3). The surgical indications for the 5 patients who underwent revision TKA were medial laxity in 4 patients and an iatrogenic lateral condyle fracture in 1 patient.

The preoperative Kellgren–Lawrence grade in the most affected knee compartment was III in 8 patients and IV in 77 patients. The mean preoperative tibiofemoral alignment was 13.6° (SD 7.2°, range 2°–27°) for patients

with preoperative varus deformities and -14.4° (SD 6.1° , range -1° to -31°) for patients with preoperative valgus deformities.

All patients were allowed full weight bearing immediately postoperatively. Physiotherapy and range-of-motion exercises were started on postoperative day 1.

The mean follow-up duration was 24.7 months. No intraoperative complications were reported. Four patients experienced postoperative complications. Two patients had stiffness, which improved after physiotherapy in 1; the other patient required a manipulation under anesthesia. One patient developed an infection, which required readmission and revision surgery, and 1 patient had a hematoma, which was aspirated and resolved. No patients reported postoperative instability. The 30-day return to hospital rate was 2.4% (because of infection and hematoma).

DISCUSSION

Multiple reports have focused on the use of posterior-stabilized inserts and VVC inserts in complex primary knee arthroplasty; less attention has been paid to semiconstraint liners such as CPS.^{13,14} The use of the VVC design has been advocated if a posterior-stabilized insert does not provide the required stability.¹⁵ Deficient collateral ligaments, bone loss and inability to obtain symmetric gap balancing, especially laxity in flexion, are common indications.¹⁶ The exact amount of instability or discrepancies in gap balancing leading to negative outcomes is widely unknown. Therefore, surgeon discretion is the main factor leading to conversion of the implant to one with more constraint. There are limited data on the indications for semiconstraint liners, but comparable clinical and radiologic outcomes with VVC and posterior-stabilized liners in primary nonstemmed TKA implants have been reported, with similar survivorship in the short and medium term.^{17–20}

One concern is that adding more constraint to the implant to achieve appropriate stability will decrease its survival. A larger post as well as asymmetric contact forces between the tibia and femur have the potential to increase polyethylene wear. Therefore, the CPS polyethylene bearing is highly cross-linked and infused with vitamin E. Reducing oxidative stresses with vitamin E is thought to improve the mechanical properties of the polyethylene and reduce the risk of post fracture.²¹ Higher constraint can also lead to increased stress at the implant–bone or cement–bone interface.²² This may predispose to loosening and lower long-term survivorship of the implant. Although selection of the constraint level is often predicted by the preoperative coronal alignment and physical examination of the collateral ligaments,²³ the final choice should be based on the final intraoperative assessment with trial components, with analysis of the flexion and extension gaps.²⁴

Although there are limited studies on semiconstrained liners, Lombardi and colleagues²⁵ conducted a retrospective review of their 10-year experience with CPS implants (with maximal constraint, currently the Vanguard complete knee system, Zimmer Biomet). They performed primary TKA on 61 knees, with an average follow-up duration of 5.6 years. They reported an overall improvement in range of motion, Hospital for Special Surgery (HSS) score, and Knee Society (KS) clinical score and function score. The revision rate was 11%, with no revision being due to aseptic loosening. Sumino and colleagues²⁴ reported that the Flexible Nichidai Knee system (Nakashima Medical) provided relatively high varus–valgus stability without the requirement for stem extensions in patients with severe knee deformities and ligamentous laxity. Johnson and colleagues²⁶ performed a retrospective analysis of 239 patients who underwent TKA with the Total Condylar III system (Johnson & Johnson) and found no evidence of loosening, high patient satisfaction scores and high postoperative outcome scores; the average follow-up duration was 5.5 years.

Most authors recommend using VVC inserts in cases of severe bone loss or ligamentous laxity, with reports of excellent outcomes at 5 years²⁷ and 7 years²⁸ without documented aseptic loosening. An overall 9-year survival rate of 93.6%²⁹ and a 10-year survival rate of 96%⁹ with regard to aseptic loosening have been reported with the use of the VVC design. There is no consensus as to how much laxity mandates the use of a VVC inset, but its use when there is persistent intraoperative laxity greater than 7 mm–10 mm has been suggested.¹⁰

Traditionally, use of the least degree of constraint necessary to achieve appropriate stability has been recommended. However, the frequency of favourable outcomes with the use of more constraint is increasing, as are revision rates for instability. Thus, the surgeon must find a balance between overconstraining, with the aforementioned disadvantages and underconstraining, with resulting symptomatic instability. To the best of our knowledge, there are no randomized or head-to-head studies comparing semiconstrained implants such as the CPS to VVC designs. Our complication rate was 4.7%, none of which involved aseptic loosening or instability. Our short-term follow-up findings show that the semiconstrained CPS implant may be an excellent substitute for the VVC implant.

Some authors advocate the use of tibial stems for patients with severe varus deformity, with a lower rate of radiographically observed aseptic loosening and revision surgery than with nonstemmed tibial components being reported.^{6,7,30,31} In most studies evaluating VVC implants, stem extensions have been used.^{32,33} In contrast, in a retrospective study, Anderson and colleagues³⁴ concluded that using VVC implants without stem extensions in knees with severe valgus led to functional improvement, with no

substantial complications at mid-term follow-up. In the present study, a stemmed tibial component was used in 63% of patients, and they showed similar radiologic outcomes with equal survival as the patients with non-stemmed implants. The treating surgeons recognized that the increased level of constraint might increase stress transfer to the implant–bone interface and felt it might be warranted to use a short stem as a load-sharing device, especially in poor-quality bone.

Limitations

Limitations to our study include its retrospective design and use of data from a single centre. Also, it was impossible to take into account technical variations and decision-making of all the surgeons over the course of the study.

CONCLUSION

Given our similar short-term survival rates, we believe that semiconstrained implants such as the CPS are a good substitute for VVC implants to achieve the necessary stability in knees that are difficult to balance while using the least amount of constraint. Although our experience is limited, it provides early evidence that the CPS polyethylene liner is an effective implant with excellent short-term survivorship. Adding a stem did not show any functional or radiologic differences at short-term follow-up. Long-term follow-up of these cases will be important to identify adverse outcomes such as loosening or polyethylene-related problems. Future studies focusing on robotic-assisted surgery may allow better quantification of soft-tissue imbalance and render the process of deciding between semiconstrained and constrained implants more standardized.

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