

# Reconstructive REVIEW

OFFICIAL JOURNAL OF THE



**Joint Implant Surgery and Research Foundation**

Strategic Alliance with



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## Joint Implant Surgeons



Orthopaedic Surgeons Specializing in  
**Joint Replacement**  
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of the Hip, Knee, and Shoulder

# Reconstructive Review

A Journal Published by the Joint Implant Surgery & Research Foundation



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## JISRF Announcements



**Timothy McTighe, Dr. HS (hc)**  
Executive Director, JISRF  
& Editor-in-Chief  
Reconstructive Review

This makes our third edition for 2013 and lays the foundation for 2014. I am pleased to announce that we intend to step up to publishing quarterly issues (**March, June, September & December**). We are also in the process of placing our manuscript services (Editorial Manager) into place by the end of the first quarter of 2014. This will make it easier for manuscript submissions along with providing our reviewers up-to-date tools for the review process.

I am very pleased to announce JISRF's support to Operation Walk. Operation Walk USA is an independent medical humanitarian organization that provides free hip or



knee replacement surgeries to patients in the United States. Operation Walk USA benefits US citizens and permanent residents who do not qualify for government assistance programs and cannot afford surgery on their own. Operation Walk USA is committed to helping those in need by restoring their mobility, self-dignity and productivity, thus helping them return to work and their social activities. Currently, Operation Walk USA takes place once a year, in December.

JISRF was pleased to make a \$10,000.00 donation in 2013 to help support this endeavor. We would like to encourage all within the Orthopaedic Community to get involved with this activity.

**EXECUTIVE COMMITTEE** for Operation Walk: Adolph V. Lombardi, Jr., MD, FACS; Douglas A. Dennis, MD; Lawrence D. Dorr, MD; Carlos J. Lavernia, MD; Chitranjan S. Ranawat, MD; and Giles R. Scuderi, MD ([www.opwalkusa.com](http://www.opwalkusa.com))

Timothy McTighe, Dr. HS (hc)  
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# *Strategic Alliance Announcement*



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DARF, founded in 2005 by Dr. Thomas K. Donaldson, has a focus on outcome studies and basic science with major emphasis on implant retrievals. His ongoing collaboration with Ian Clarke, PhD provides a synergy between the laboratory and clinical surgical science. Both men are Board Members of JISRF and have a significant working relationship with its Executive Director Timothy McTighe Dr. HS (hc).

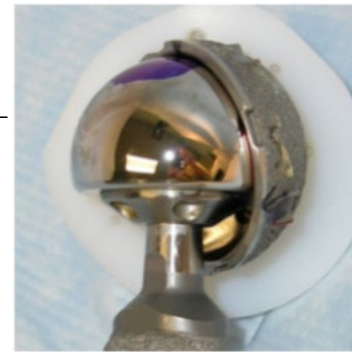


*Ian Clarke, PhD & Thomas K. Donaldson, MD*

JISRF, founded in 1971, has had significant experience with continuing medical education, product development, and clinical surgical evaluation of total joint implant devices.

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Direct any questions regarding the submission process, or requests for reprints to David Faroo, Director of Communications, JISRF, 46 Chagrin Plaza #117, Chagrin Falls, Ohio 44023, [dfaroo@jisrf.org](mailto:dfaroo@jisrf.org).

There is no subscription charge for receipt of this publication. This is done as a service keeping with the overall mission of JISRF.

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5. Suggested structure of articles:
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- Historical Reviews
- Letters to the Editor  
(We welcome letters to the editor and acceptance is at the sole discretion of the Editor.)
- Original Articles
- Surveys

The emphasis for these subjects are to address real life orthopaedics in a timely fashion and to encourage the participation from a broad range of professionals in the orthopaedic health care field.

We will strive to be responsible and reactive to the needs expressed to our editors and all members of JISRF. We anticipate our format will evolve as we move forward and gain more experience with this activity. Your opinion is a critical step to our motivation and overall success. Please don't hesitate to communicate with us.

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The specific and primary purposes are to operate for scientific purposes by conducting medical research of improvements in medical and surgical methods and materials for preserving and restoring the functions of the human body joints and associated structures which are threatened or impaired by defects, lesions or diseases.

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This phase will include an expansion of our world renowned executive health and wellness practice, The Greenbrier Clinic, which will be bolstered by a world-class sports medicine program, including an orthopedic surgery center and athletic performance/rehabilitation facility, all led by the Founder of the American Sports Medicine Institute, Dr. Jim Andrews and Chair of Cleveland Clinic Innovations, Thomas Graham. Rounding out the Institute's services will be a first-



in-class plastic and cosmetic surgery and Lifestyle Enhancement Academy, helping people look and feel their best. Physicians, universities, research foundations, medical journals and other healthcare industry leaders, all of whom are on the cutting edge of medical technology, research and care, have committed to join the project and establish an international research and education destination or “think tank” to stimulate research, drive innovation, force change and redefine how the world approaches health, wellness and longevity.

The Institute's facility, designed by Willie Stokes, will feature Georgian architecture similar to the resort's façade, a replica of the Springhouse, the site of the famous sulphur springs and special guests suites for patients and their families. Jack Diamond, President and CEO, and Mark Krohn, COO, are leading the development of this exciting project and are actively looking for other physicians and medical thought leaders to be involved.

For more information, please contact:

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# The Fate of the PCL in Cruciate Retaining TKA A Critical Review of Surgical Technique

*Sherif M. Sherif, M.D.†, Matthew V. Dipane, B.A.†, Edward J. McPherson, M.D., FACS†*

## Abstract

This study prospectively reviews 368 consecutive primary TKA's, documenting the status of the PCL during 3 stages of the TKA procedure: 1) at initial arthrotomy, 2) after all bone cuts were made, and 3) after final balancing with all components in place. We found at initial presentation that 94% of PCL's were intact. After the bone cuts were made only 51% of PCL's remained intact. Finally, after knee balancing and all implants were in place, only 33% of PCL's remained intact. Furthermore, 43% of PCL's were attenuated at the final evaluation stage and were at risk for late PCL stretch-out. In this series, patients with a deficient or attenuated PCL were treated with an anterior stabilized bearing that could be utilized with a cruciate retaining femoral component. We advocate that a cruciate substituting bearing be routinely available when undertaking a cruciate retaining TKA.

**Key words:** TKA, CR TKA, PCL, ACL, Anterior Stabilized, Primary

**Level of Evidence:** AAOS Therapeutic Study Level III

## Introduction

Primary total knee arthroplasty (TKA) is a successful procedure for patients suffering from advanced gonarthrosis of the knee [1,11,31,47]. As technology has evolved, several different TKA designs have been utilized. These include the PCL retaining TKA (CR TKA), the posterior stabilized TKA (PS TKA), and the anterior stabilized TKA (AS TKA). The AS TKA is also referred to as an ultra-congruent TKA. Clinical success has been reported with all three knee designs [29,32,33,42,44].

There is still vigorous debate among surgeons on which knee design should be used routinely for primary TKA. Each knee design has distinct merits and drawbacks. Surgeon preference in design selection is

most often based upon his/her prior surgical training and personal experience. A common focus of debate centers on the integrity of the PCL during and after TKA [39,40,41,43,56,57].

Many surgeons feel that the PCL cannot be preserved in a consistent fashion. A number of reasons exist for this line of thinking including knee deformity requiring PCL release, PCL contracture due to the arthritic process requiring release, and PCL damage during surgical technique. These issues cause some surgeons to favor the removal of the PCL with routine conversion to an AS or PS TKA [5,13,14,15,52,54,57]. The literature documents the effects of late knee instability in CR TKA which is

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thought to be a result of late PCL laxity creating a flexion instability pattern [13]. Flexion instability clinically presents with recurrent knee effusion, activity related pain, the inability to reciprocate stairs, and difficulty arising from a low chair [18,19,23].

The literature provides scant information regarding what happens to the PCL during primary CR TKA. This study was conducted to prospectively examine that fate of the PCL during three stages of the CR TKA procedure. We believe that the PCL is more frequently damaged than what is reported in existing literature.

## Materials and Methods

Between October 2007 and October 2012, 368 primary TKA's were performed at a single institution by the senior author (EJM). The surgical technique remained consistent throughout the study period (see Surgical Technique). The assessment of the PCL was performed with the knee at 90° of flexion. The ligament was visually inspected and subjectively palpated. The PCL was assessed during three stages of the TKA procedure. The first evaluation was upon inspection of the knee after initial arthrotomy. During the first evaluation we also assessed the ACL before its removal. The ACL was inspected and rated as being intact, attenuated, or completely deficient. We defined a ligament (ACL or PCL) as "attenuated" when more than 50% of the fibers were deficient or the ligament was felt to be lax by direct palpation. The initial evaluation of the PCL was made after removal of the ACL and all intercondylar osteophytes. The second evaluation was made after completing all femoral and tibial bone cuts, but before knee ligament balancing. The PCL was assessed during this stage with laminar spreaders placed between the femur and tibia at 90° of flexion. The laminar spreaders were opened until complete flexion gap distraction was obtained. The PCL was assessed again as being intact, attenuated, or completely deficient. The third evaluation stage was conducted after knee ligament balancing with components cemented and the final modular tibial bearing placed. At final assessment, the PCL was documented as retained intact, retained attenuated, partially released, or removed. We define the PCL as partially released when more than 50% of the fibers are released from the femoral attachment.

All patients were followed for a minimum of six months. Functional performance was graded us-

ing the Knee Society Score [26]. All charts were reviewed for complications and implant failures. Failure was defined as implant removal or recommended implant removal. A knee complication was defined as any reoperation on the knee where the TKA implants were retained (this includes cases of modular tibial bearing exchange). Medical complications were recorded, but we do not report on these events so as to focus on the results of the surgical technique.

## Surgical Technique

All TKA's were preformed using a less invasive paramedical incision with a medial parapatellar arthrotomy [10,30]. The incision was made long enough to allow for comfortable access and exposure to the knee. The Vanguard Total Knee System™ (Biomet, Warsaw, IN) was used in all cases. A cruciate retaining femur was inserted in all cases. Three polyethylene tibial bearing designs were used: a flat design, a dished posterior design, or an anterior stabilized (also known as "ultracongruent") bearing [46]. The anterior stabilized bearing had an extended anterior lip which was of the same height of the Vanguard posterior stabilized post. Additionally, the posterior lip was extended 50% more than the dished tibial insert. The selection of each bearing design depended upon the flexion stability of the knee. An anterior stabilized bearing was used whenever the PCL was deficient or removed.

An intramedullary guide was used to cut the distal femur at a 5° valgus cut angle. Rotation of the femur was based upon the Anterior-Posterior axis as described by Whiteside [58]. Sizing of the femur was measured using a posterior reference technique. The proximal tibial bone cut was made using an extramedullary guide system. A bone block around the PCL was not used. A posterior slope was cut in all cases parallel to the medial compartment slope [6,7,8,9,24,27,28]. Coronal and sagittal plane balancing was performed utilizing a modified spacer block technique. Specifically, a trial femur was inserted along with a tibial trial sans a keel. Rotation of the tibia was set to provide congruent femoral-tibial mating in deep flexion. All patellae were resurfaced with a 3 peg polyethylene reduced thickness implant (Biomet, Warsaw, IN), a subset of implants that are 15% thinner than the standard patellar implant. All implants were cemented using Cobalt cement (Biomet, Warsaw, IN) without antibiotics. All surger-

---



ies were performed with body exhaust suits (Stryker, Kalamazoo, MI) in non-laminar flow rooms. Anesthesia consisted of a general anesthetic combined with spinal anesthesia with low-dose intrathecal preservative free morphine sulfate (0.1 mg).

## Results

The results of the initial ligament assessment are presented in Tables 1 & 4. For the anterior cruciate ligament [2], 15% were judged to be attenuated while 18% were deemed deficient. For the posterior cruciate ligament, 5% were judged to be attenuated and 1% of the ligaments were assessed deficient.

The second assessment stage of the PCL was made after initial bone cuts. These results are listed in Table 2. At this stage, 30% of the PCL's were judged to be attenuated. In most instances, this occurred due to the saw blade cutting the anterolateral bundle of the PCL. After making all bone cuts, 19% of the PCL's had been removed. These ligaments were either com-

pletely cut by the saw blade or removed with the resected proximal tibia.

Tables 2a & 2b are subsets derived from Table 2. Specifically, Table 2a details the fate of the 188 PCL's assessed as intact after the bone cuts were made. In this group 26% were partially released and 9% were removed in order to balance the knee. Table 2b details the fate of the 112 PCL's assessed as attenuated after the bone cuts were made. In this group 5% were partially released and 4% were removed in order to balance the knee.

The results of the final PCL assessment stage are presented in Table 3. Of the 368 TKA cases presented in this study, only 33% maintained completely intact PCL's. A further 28% of PCL's were retained but assessed as attenuated (injured during technique). Lastly, 15% of the PCL's in this series were partially released (for knee balancing) and 24% were removed.

We experienced 29 complications (8%) which are listed in Table 5. The most common complication we encountered was arthrofibrosis requiring manipulation (4%). There were 21 failures (6%) in this series

at a maximum follow-up of 72 months (range 6-72 months). Failures are listed in Table 6. The most common reasons for failure were chronic periprosthetic infection (1.4%) and supracondylar femur fracture (1.4%). Interestingly, we encountered 3 cases (0.8%) of metal hypersensitivity to Nickel. This was based upon the Lymphocyte Transformation Test (LTT) described by Hallab [21,22]. These implants were revised to Nickel-free implants.

Table 1  
Stage I: PCL Inspection at Arthroscopy

PCL Initial	N = 368	
Intact	N = 348	94%
Attenuated	N = 17	5%
Deficient	N = 3	1%

Table 2  
Stage II: PCL Inspection at Bone Cuts

PCL after Bone Cuts	N = 368	
Intact	N = 188	51%
Attenuated/Damaged	N = 112	30%
Removed	N = 68	19%

Table 2a  
Fate of 188 Intact Ligaments at Bone Cuts

188 Intact after Bone Cuts	N = 188	
Retained	N = 123	65%
Partially Released	N = 49	26%
Removed	N = 16	9%

Table 2b  
Fate of 112 Attenuated Ligaments at Bone Cuts

112 Attenuated after Bone Cuts	N = 112	
Retained	N = 102	91%
Partially Released	N = 6	5%
Removed	N = 4	4%

Table 3  
Stage III: PCL Inspection at Closure

PCL Final Assessment	N = 368	
Retained Intact	N = 123	33%
Retained Attenuated	N = 102	28%
Partially Released	N = 55	15%
Removed	N = 88	24%

Table 4  
ACL Inspection at Arthroscopy

ACL	N = 368	
Intact	N = 245	67%
Attenuated	N = 55	15%
Deficient	N = 68	18%

Table 5: Complications

Manipulation for Arthrofibrosis	14
Superficial Wound Split	5
Traumatic Arthroscopy (Fall)	4
Bearing Change for Hyperextension Laxity	2
Lateral Release for Patellar Subluxation	2
Flexion Laxity after Fall (Bearing Change)	1
Hematoma Evacuation	1

Table 6: Failures

PCL Initial	N = 368	
Intact	N = 348	94%
Attenuated	N = 17	5%
Deficient	N = 3	1%

## Discussion

The posterior cruciate ligament is the strongest ligament in the knee joint [3,4,55]. The biomechanical importance of the PCL is dictated by its anatomy. The tibial attachment is relatively compact and extra-articular, inserting approximately 1cm below the joint line on the posterior tibial surface. The PCL is the primary restraint to tibial posterior drawer at all angles of knee flexion.



The posterolateral and posteromedial structures of the knee are responsible for posterior knee stability as the knee nears extension. This explains why isolated rupture of the posterior cruciate ligament does not lead to knee instability with walking [20,53]. Additionally, the PCL has a proprioceptive function. Studies using immunohistochemical stains specific for neural tissue demonstrate the presence of mechanoreceptors in the PCL [2,38].

Osteoarthritis of the knee causes disabling pain and affects all knee structures [2]. Contracture and fibrosis of the PCL is part of the arthritic process and may compromise the function of the PCL [59]. For this reason, when performing TKA, surgeons are divided into two main camps when choosing a specific TKA implant system: those who prefer the removal of the PCL and those who favor its preservation. Surgeons who prefer to remove the PCL substitute the ligament with one of two designs. The first option is the posterior stabilized knee. This design has a central tibial polyethylene post which articulates with a femoral cam preventing the femur from dislocating anteriorly in flexion [52,56]. The second option is the anterior stabilized knee. In this design, instead of a central polyethylene post, there is a raised anterior lip of similar height as a posterior stabilized post that resists anterior femoral translation similar to the PS TKA design [45].

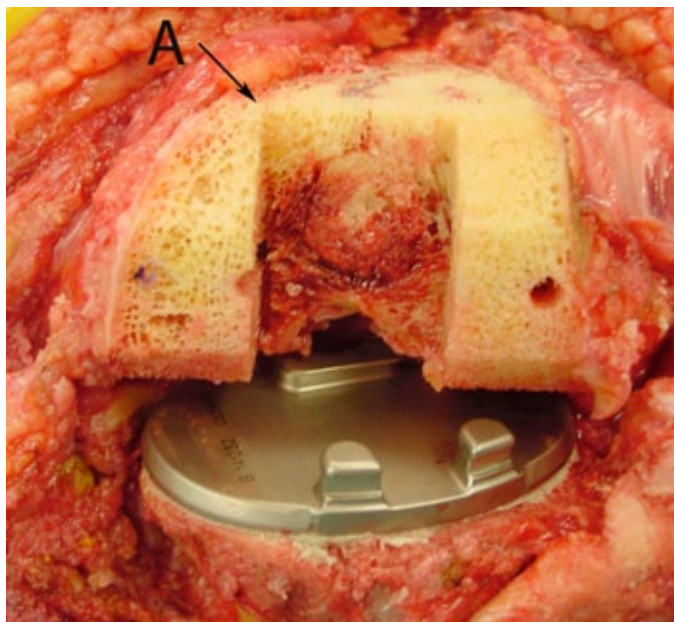


Figure 1

*Intra-operative photograph during primary right PS TKA. This photo emphasizes the significant amount of bone that is removed in the middle of the femur to accommodate the femoral box. A wide box cut in a small femur leaves little condylar bone and may cause fracture. Note the area of lateral femoral condyle (A) where fracture may occur.*

Surgeons that eschew cruciate sacrificing designs cite several subjective reasons. First, compared to the PS TKA design, the CR TKA is generally felt to be “less noisy.” There tends to be fewer flexion clicks and rattles which can sometimes concern patients. Furthermore, some surgeons are concerned by the amount of bone removed from the intercondylar notch in some PS TKA designs which can be significant. This is especially relevant in small sized femurs (Figure 1) [34]. Additionally, reports suggest an increase in retrocondylar bone density loss in PS TKA systems. The central metallic box bears load centrally which reduces mechanical loads in the femoral condyles [50]. Flexion laxity with complete removal of the PCL is also a concern to surgeons. If the flexion gap is loose, the risk for mid-flexion instability and femoral cam jump is increased [16,17,37].

Retaining the PCL is not as simple as it sounds. First, modern prosthetic designs that focus on high flexion advocate recreating the native posterior slope. This is problematic with Asian-Pacific patients where native slope is reported as high as 10-13° [12]. Cutting the tibial bone at this slope may remove the entire PCL attachment on the tibia. Secondly, less invasive techniques make it difficult to preserve a bone island around the PCL attachment on the tibia. A bone island, while protective of the PCL, limits the amount the tibial component can be rotated. Thus,

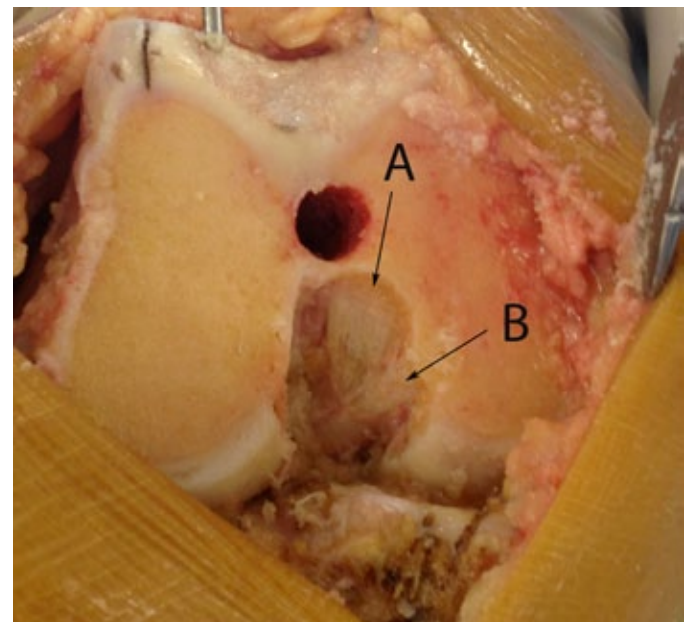


Figure 2

*Intra-operative photograph during primary right CR TKA. This photo shows the two distinct bundles of the PCL: the posteromedial (PM) bundle (A) and the anterolateral (AL) bundle (B). Note that the AL bundle is anterior and is the most susceptible to saw cut damage.*

many surgeons avoid preserving a bone island to allow for rotation of the tibial component for optimal mating with the femur. Furthermore, the anterolateral bundle of the PCL inserts on the tibia anterior to the posteromedial bundle (Figure 2). This bundle is important in maintaining midflexion stability [4,55].

Knees with significant deformity require more extensive releases, including the PCL. “Balancing” the PCL in flexion with releases either off the femur or tibia can significantly compromise the integrity of the ligament [48,51]. For all of these reasons, a weakened PCL is of concern. A CR TKA with a significantly weakened PCL is at risk for late flexion instability as the damaged ligament can stretch out over time.

This study provides a humbling review of the status of the PCL when using a CR TKA design. First we describe that 6% of PCL’s are either attenuated or deficient at initial presentation. This incidence of attenuated PCL’s is in accordance with the literature [2,5,46]. This is an important observation considering that many surgeons exclusively use CR TKA designs. Surgeons should be ready to substitute for the attenuated/deficient PCL when using a CR TKA system.

We also documented that 33% of ACL’s are either attenuated or deficient at initial presentation. This observation is not novel, but the data reinforces the concept that many knees which become arthritic may be caused by traumatic ligament injuries. This has significant bearing to knee arthroplasty. First, a mobile bearing unicompartment knee arthroplasty is absolutely contraindicated when the ACL is deficient. Furthermore, there are currently two TKA designs soon to be introduced that preserve both the PCL and ACL (Biomet, Warsaw, IN & Wright, Arlington, TN). Based on this data, an ACL/PCL preserving TKA design could not be used routinely in clinical practice.

In the second evaluation stage, after all bone cuts were made, only 51% of the PCL’s remained intact. There are two main reasons to explain our high rate of PCL damage. First, our surgical technique focused on a high flexion protocol. This was dictated by our city’s cultural diversity (Los Angeles, CA) and our relative proximity to the Pacific Rim countries where knee flexion is highly valued. Our standard TKA protocol included cutting the tibia with a native posterior slope [36,60]. With the removal of posterior tibial bone, a significant amount of the PCL inserted into the proximal tibia was removed, weakening the PCL

or removing it altogether. Furthermore, we did not use a preserving bone block around the tibial PCL insertion. Our priority was to optimize tibial component rotation with congruent implant mating into deep flexion. Prior to this study, we observed that preserving a bone island around the PCL impeded optimal tibial component mating with the femur. The PCL’s damaged or removed in this phase of the TKA procedure were based solely on mechanical bone cuts. Altering surgical technique in this phase may mitigate the incidence of PCL damage, but the surgeon must be willing to accept the trade off. In our opinion, decreasing posterior slope and limiting tibial component rotation with a protective PCL bone block may limit flexion range and may cause kinematic dysfunction with sub-optimal femoral-tibial mating [40,49].

In the third evaluation stage, after knee balancing was complete and all implants were in place, only 33% of PCL’s remained intact. In 43% of our TKA’s the PCL was judged to be attenuated either by mechanical damage or surgeon release for knee balancing. This latter group, in our opinion, is at risk for late flexion and/or midflexion instability. As time progresses, the attenuated PCL can be further damaged by several mechanisms. These include manipulation for arthrofibrosis, osteolysis, trauma (i.e., falls), and PCL stretch out with arduous functional activities. We feel strongly that this group should be treated with a cruciate substituting design. In this study, our solution was to insert an anterior stabilized bearing. For us, this was a simple intra-operative conversion as the AS bearing mates with the CR femur. The anterior stabilized bearing obviates the need to change to a posterior stabilized knee system in the middle of the TKA procedure, saving valuable OR time [45].

Lastly, in our final evaluation, 24% of PCL’s were completely lost either by mechanical damage or surgeon release for balancing. This group was treated with a cruciate substituting design which again utilized an anterior stabilized bearing. We observed in this study that the anterior stabilized bearing provided acceptable function and stability across a wide variety of clinical deformities. Thus, we do not feel the need to convert to a posterior stabilized design.

Complete preservation of the PCL during primary TKA is difficult. Only one third of the PCL’s in this series remained completely intact. We advocate that a cruciate substituting bearing be routinely available when using a CR TKA. Furthermore, 40% of our PCL’s were attenuated for this group. We encourage

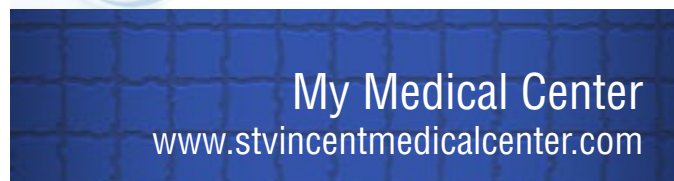
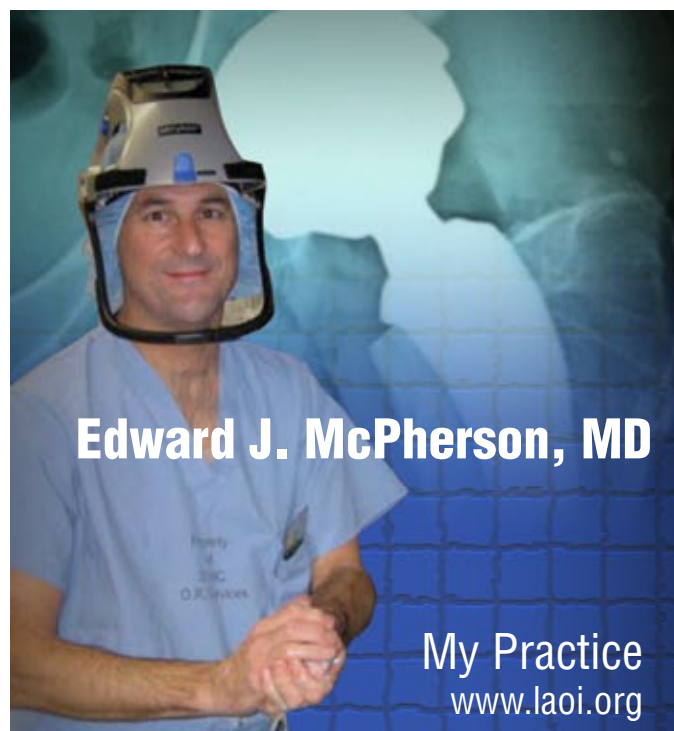
the use of a PCL substituting bearing as this group is potentially at risk for late term flexion and/or mid-flexion instability.

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# Strategies to Decrease Blood Loss in Patients Who Undergo Total Knee Replacement: A Prospective Study of One Hundred and Fifty Cases

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## Abstract

We calculated the total blood loss in a non-randomized study of 150 total knee replacements which were performed under regional anaesthesia by a mini-subvastus surgical approach without the use of a tourniquet. In all knees, tranexamic acid was used perioperatively. The skin, subcutaneous tissue and joint capsule were infiltrated with saline adrenaline prior to making surgical incision. After cementing the prostheses, the surgical wound was packed alternately with hydrogen peroxide and Feracrylum-soaked packs for 3 minutes. Tourniquet and postoperative drain were not used in any of the knees. In our series, the mean perioperative blood loss was 433 mL (SD 74), the mean RBC volume loss was 234 mL (SD 40.4), and the mean reduction in hemoglobin level was 1.6 gm/dL. The mean preoperative hemoglobin was 12.01 gm/dL (SD 1.4) and the mean postoperative hemoglobin was 10.4 gm/dL (SD 1.4). The mean preoperative hematocrit was 37.04 (SD 2.8) and the mean postoperative hematocrit was 31.29 (SD 2.7). One of our patients developed cerebral thromboembolism three days after the surgery. Postoperative hemoglobin of less than 8 g/dL was considered an indication for blood transfusion; however, none of our patients required blood transfusion in the present series.

**Study Design:** Therapeutic case series; Level of Evidence, IV.

**Keywords:** Tranexamic acid; Antifibrinolytic agent; Decreased blood loss; Total knee arthroplasty

## Introduction

Total knee arthroplasty is associated with postoperative blood loss necessitating allogeneic blood transfusion in 10% to 38% of patients [1-4]. The reported amounts of blood loss have ranged from 1,450 to 1,790 mL [5-9]. It is well known that allogeneic blood transfusion carries the risk of immunological and non-immunological adverse effects (such as a higher rate of postoperative infections and transmis-

sion of diseases), and furthermore has a high medical cost.

Several techniques are available to minimize

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the blood loss and decrease the likelihood of allogeneic blood transfusion after a total knee replacement. These techniques include pre-operative iron and erythropoietin administration where indicated, use of tranexamic acid perioperatively, infiltrating saline adrenalin intra-operatively, not using post-op drains or clamping the drain periodically, not using the tourniquet, and use of fibrin spray or glue.

The objective of this study is to evaluate the combined effectiveness of pharmacological and non-pharmacological measures to control perioperative blood loss. In the past, different studies have shown a decrease in blood loss in total knee replacement, whilst employing some specific means e.g. perioperative use of tranexamic acid, [10-13] use of minimally-invasive surgical approach, [14-16] use of regional anaesthesia, [17] use of saline-adrenaline infiltration, [18] use of hydrogen peroxide, [19] and use of Feracrylum-soaked packs [20,21]. However, we could not identify a single study in which different measures were utilized simultaneously to study their combined effect on blood loss. We wanted to evaluate if by combining the various known factors we would be able to demonstrate a synergistic effect on blood conservation.

## Materials and Methods

**Patients** –A non-randomized study was carried out on 150 total knee replacements for the treatment of osteoarthritis of the knee joint at three institutes in Bombay (now known as Mumbai), India from March 2007 to May 2008. The lead author (N.A.S.) of this paper is in private practice and considers it unethical to have a control group as the current regime is working so well. Our series is a cohort study. A retrospective analysis of prospectively collected data was performed.

Our series included only those patients who underwent unilateral total knee arthroplasty. Patients with unicompartmental replacement or bilateral total knee replacements were not included in this study. All surgeries were performed by a single surgeon (N.A.S.). Patients with a history of severe ischemic heart disease, chronic renal failure, cirrhosis of liver, and bleeding disorders, as well as those with past history of thromboembolic episode were excluded from this study. Thirty-seven patients in the present series were on anti-platelet drugs like aspirin. If aspirin was being taken at a dose greater than 75 mg, it

was reduced to 75 mg but not stopped altogether. If the dose of aspirin was 75 mg, it was continued. The average age of the patients was  $71.2 \pm 4.5$  years at the time of surgery. Table 1 shows the patient profile including the mean weight and height, which were  $75.56 \pm 9.6$  kg and  $160 \pm 6.6$  cm respectively.

**Table 1. Patient profile and results.**

1)	Age in years	$71.2 \pm 4.5$
2)	Weight in kg	$75 \pm 9.6$
3)	Height in cm	$160 \pm 6.6$
4)	Male:Female	1.5:2
5)	Preoperative haemoglobin (gm/dL)	$12.01 \pm 2.7$
6)	Postoperative haemoglobin (gm/dL)	$10.4 \pm 2.8$
8)	Mean haemoglobin fall (gm/dL)	$1.6 \pm 0.6$
9)	Preoperative haematocrit (%)	$37 \pm 5.6$
10)	Postoperative haematocrit (%)	$31 \pm 5.4$
11)	Mean total blood loss (mL)	$433 \pm 148$

The baseline hemoglobin level, haematocrit, and coagulation profile with platelet counts were measured preoperatively. The hemoglobin and haematocrit values were checked again on fifth postoperative day. The mean reduction in hemoglobin was calculated by subtracting the mean postoperative hemoglobin level from the mean preoperative hemoglobin level.

### Use of Tranexamic Acid

At the time surgery, tranexamic acid was given in the dose of 15 mg/kg intravenously 5 to 10 minutes before making the skin incision. Second dose (10 mg/kg intravenously) was repeated 3 hours after the first one, and the third and final dose (10 mg/kg intravenously) was given 3 hours after the second dose.

### Surgical Procedure

All total knee replacements were performed by the same surgeon (N.A.S.) through a minimally invasive subvastus approach [16] under regional anaesthesia. Tourniquet was not used in any of the patients. Spinal anaesthesia with Sensorcaine (0.5%) was used for all patients. All patients had 30 to 50 mL of saline with dilute adrenaline (1:300,000) infiltrated into the skin, subcutaneous tissues, and joint capsule before taking surgical incision. All patients underwent a mini-subvastus approach, and a L-shaped capsulotomy incision was made. Standard surgical techniques for intraoperative haemostasis were used. The NexGen and LPS High-flex cemented total knee endoprosthesis (Zimmer, U.S.A.) system was used for

all total knee replacements. After final implantation and prior to wound closure, the wounds were alternately packed with hydrogen peroxide and Feracrylum for three minutes. No surgical drains were used in our series.

Prophylactic antibiotic therapy consisted of intravenous administration of 1.5 gm of cephalosporin (cefuroxime) immediate preoperatively followed by 750 mg every 8 hour for 2 days postoperatively. None of the patients received any pharmacologic prophylaxis against venous thromboembolism but TED stockings were utilized postoperatively for 6 weeks. While in the hospital, patients were examined daily for any clinical symptoms of deep-vein thrombosis. All surgical and medical adverse events and any thromboembolic events occurring (if any) during the six weeks after surgery were recorded at the time of the follow-up visit with the surgeon. Femoral nerve catheter was inserted with the help of a nerve stimulator for postoperative pain control.

Assessment of intraoperative and postoperative blood loss

All patients had a complete blood count including haematocrit (Hct) before operation and on the fifth day after the procedure. By this time, the patients were haemodynamically stable and thus fluid shifts would have been largely completed. The height and weight were recorded preoperatively and the body mass index was calculated.

### *Calculation of Blood Loss*

In our series, the patients' blood volume (PBV) was calculated using the formula of Nadler and colleagues [22].

$$PBV = k1 \times \text{height(m)}^3 + k2 \times \text{weight(kg)} + k3$$

where  $k1 = 0.3669$ ,  $k2 = 0.03219$ ,  $k3 = 0.6041$  for men and  $k1 = 0.3561$ ,  $k2 = 0.03308$ ,  $k3 = 0.1833$  for women

Multiplying the PBV by the haematocrit will give the total red cell volume. Any change in red cell volume can therefore be calculated from the change in haematocrit [7,23].

Total red blood cell (RBC) volume loss = PBV x (Hctpreop - Hctpostop) [7,23].

Every 100 ml of concentrated blood from the blood recovery system corresponded to 54 ml red cells.

As blood loss is occurring, the patient's circulating volume will tend to fall. However, simultaneous shift of fluid into the circulating compartment and fluid

administered perioperatively maintains the circulating volume, although with increasingly more diluted blood (i.e. isovolaemic haemodilution), and the haematocrit gradually falls [7]. Consideration was given to the potential effect on calculation of this perioperative retention of fluid. Studies in cardiac surgery have demonstrated retention of approximately 2 Litres of fluid. Fluid retention in orthopaedic surgery has not been accurately studied but could perhaps be significant. Since only one-eighth of body water is in the circulating compartment (which is, on average, 5 Litres), even 2 Litres of retained fluid would amount to a maximum of 5% inaccuracy in our calculation with probably no bearing on our conclusions [7].

It has been proven and generally believed that direct blood loss estimation is not accurate and denotes much lesser blood loss than what is estimated by indirect methods. We have not estimated direct blood loss because we realized that when tourniquet is not being used there is a lot of spillage around the drapes and because a drain is not used in our series, there is ecchymosis in and around the knee region suggestive of blood loss occurring in the soft tissues later on.

### *Assessment of Deep-Vein Thrombosis*

In our study, no routine postoperative duplex ultrasonography was undertaken for screening of postoperative venous thromboses and therefore, we are unable to comment on the true incidence of postoperative venous thromboses. However, we recorded the presence or absence of the Homans' sign and swelling of the legs for 6 weeks postoperatively. Homans' sign is a sign of deep vein thrombosis (DVT). A positive sign is present when there is resistance (not pain) in the calf or popliteal region with examiner's abrupt dorsiflexion of the patient's foot at the ankle while the knee is fully extended.

## **Results**

In this non-randomized, study of 150 total knee arthroplasty patients, the results show significantly less blood loss with a mean perioperative blood loss of  $433 \text{ mL} \pm 148 \text{ mL}$  (SD 74). The distribution of patients in different range of blood loss is shown in Figure 1. The mean RBC volume loss was 234 mL (SD 40.4) and the mean reduction in hemoglobin level was 1.6 gm/dL. The mean preoperative hemoglobin was 12.01gm/dL (SD 1.4) and the mean postoperative hemoglobin was 10.4 gm/dL (SD 1.4). The mean

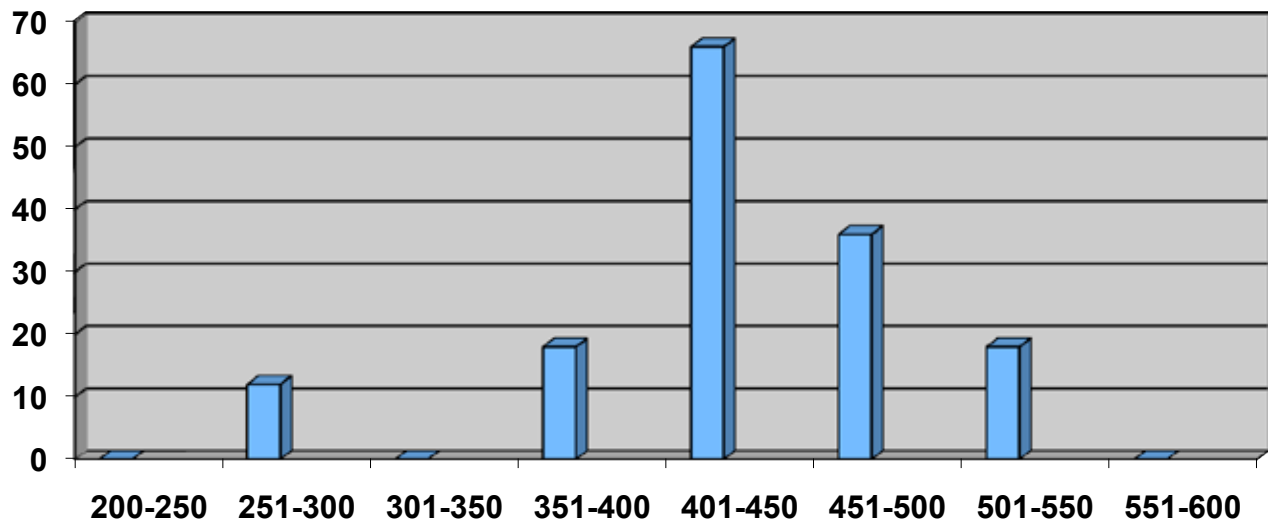


Figure 1. Distribution of total blood loss in mL. (X-axis) versus number of patients (Y-axis).

preoperative haematocrit was 37.04 (SD 2.8) and the mean postoperative haematocrit was 31.29 (SD 2.7). One of the patient in the present series developed cerebral thromboembolism three days after the surgery. Postoperative hemoglobin of less than 8 gm/dL was considered as indication for blood transfusion; however none of our patients required blood transfusion intraoperatively or postoperatively.

Apart from this study, the lead author (N.A.S.) has now an extensive experience of approximately 2,800 total knee replacements that were performed using the current regime, and only one patient out of 2,800 cases has required blood transfusion.

Table 2 shows the details of the results of our study and its comparison with the results of other similar studies.

Table 2. Comparison between results of the current study and the results of other similar studies.

	Parameters	Yamasaki et al. <sup>53</sup>	Camarasa et al. <sup>42</sup>	Our study
1.	Total blood loss (mL)	1349 ± 478	1099 ± 535	433 ± 148
2.	Hb (diff.)	1.7 ± 1.2	2.5 ± 1.0	1.6 ± 0.6
3.	Hct. (diff.)	5 ± 3.5	6.8 ± 3.0	6 ± 5.4
4.	Preop Hb (gm/dL)	12.8 ± 1.3	12.4 ± 1.0	12.01 ± 2.7
5.	Postop Hb (gm/dL)	11.1 ± 1.2	10	10.4 ± 2.8
6.	Preop Hct.(%)	38.6 ± 3.6	36.2 ± 2.7	37 ± 5.6
7.	Postop Hct.(%)	33.7 ± 3.5		31 ± 5.4

## Discussion

Blood loss management is an important issue in total knee replacement surgery. It should be made as simple as possible and should rely on common sense while also being cost-effective and having a low risk of complications [24]. Historically, correction of blood loss in surgical patients has been by transfusion of allogeneic blood to maintain or to restore the haematocrit and haemoglobin (Hb) level close to normal. However, allogeneic blood transfusion can lead to various adverse consequences such as transmission of infectious diseases, immunological reaction due to a mismatched transfusion, and increased likelihood of postoperative infection. Other effects of allogeneic blood transfusion such as multiple-organ failure or mortality have been attributed to immunomodulation by pro-inflammatory mechanisms. Allogeneic blood transfusion also adds to the cost of an operation, all the more as it has been shown to be associated with increased morbidity and prolonged hospital stay [25].

Cell salvage is another blood-saving procedure used for management of perioperative blood loss. This includes re-infusion of blood drained within six hours after operation using cell salvage. Blood shed during operation may be altered by irrigation fluid, air and cement and should therefore be washed before re-infusion to avoid coagulopathy [24]. Perioperative blood salvage has been shown to be beneficial in cases of blood loss exceeding 1000 mL but is not considered to be cost-effective in primary arthroplasty if other effective blood-saving measures have

already been taken. Its use is generally restricted to specific indications in which the anticipated blood loss is very high, such as revision total hip replacement. Postoperative cell salvage is not always cost-effective since the volume of blood recuperated is unpredictable [24]. The reported mean volume of re-infused blood has ranged between 360 mL and 880 mL [26]. It can be used in combination with other blood-saving measures if the anticipated blood loss is high, or in patients with a small blood volume and a low preoperative Hb level. Intra- and postoperative cell salvage are contraindicated in patients with infection and malignancy [24].

#### ***Autologous blood transfusion (Predonated):***

Pre-operative autologous blood predonation offers a number of theoretical advantages. It has been widely used in the recent past, but has now fallen into relative disfavour for several reasons [24,27,28]. It cannot reasonably be considered in patients who are anaemic, i.e. in 20% to 30% of patients who are to undergo total hip or total knee replacement, [29] or in those with an Hb level of >14.5 g/dL since they will not require blood transfusion. It should therefore be targeted to men with an Hb level of 11.0 g/dL to 14.0 g/dL and to women with a level of 13.0 g/dL to 14.0 g/dL whose anticipated perioperative blood loss is close to 1000 mL. In older patients who are not anaemic, the capacity of the erythropoietic marrow to react to the stimulus of blood withdrawal may prove to be inadequate. Such patients may come to operation with an Hb level lower than that before pre-donation, and will need more transfusion episodes (autologous or allogeneic) than they would have otherwise needed [24]. For the same reason, many patients simply cannot complete the pre-donation program because they become increasingly anaemic. We have not used predonation of autologous blood in our study because of the above limitations.

#### ***Fibrin Sprays and Glue***

The use of fibrin sprays and glue [30] can also help in reducing blood loss but these were not utilized in our study as they are costly.

#### ***Regional Anaesthesia***

The type of anesthetic administered may play a role in total blood loss. Controlled hypotensive spinal or epidural anaesthesia [17,31] has been shown to reduce blood loss compared with general anaes-

thesia. In the current study, all knees were operated under regional anaesthesia. However, specific measures to produce hypotension during surgery were not employed in this study.

#### ***Minimally Invasive Subvastus Approach***

In our series, all cases were performed by a minimally invasive subvastus surgical approach. This approach has shown to be associated with less intraoperative blood loss in the literature. Boerger and colleagues [15] reported a prospective, observer-blinded study of 120 consecutive patients having total knee arthroplasty. All patients were operated by one surgeon using either the mini-subvastus approach without patellar eversion or the standard parapatellar approach with patellar eversion. Patients in the mini-subvastus group lost on average 100 mL less blood and had better pain scores on day one [visual analogue scale (VAS): mean 2.4 versus 3.89].

Roysam and Oakley [14] conducted a prospective, randomized, and blinded trial with 89 consecutive primary knee arthroplasties comparing standard medial parapatellar arthrotomy with the subvastus approach. All patients received the Insall-Burstein II prosthesis inserted by a single surgeon using an identical operative technique with the only difference being the surgical approach. Assessment revealed less blood loss (527 mL versus 748 mL,  $P < .001$ ) in patients who have had a subvastus approach.

In our series, wound complications have not been a major problem with the use of a mini-subvastus approach. We have radiographs of all 150 patients (and radiographs of approximately 2,800 patients) operated by the current technique. There is no major concern of prosthetic component malalignment.

#### ***Saline Adrenaline Infiltration***

There are numerous studies on the use of saline-adrenalin infiltration in plastic, gynaecology and general surgery literature showing the reduction in blood loss. Padala and colleagues [18] showed that adrenalin and saline infiltration is safe and helps reduce intra-operative blood loss in total knee arthroplasty. In the present series, we infiltrated 1:300,000 saline-adrenalin in the skin, subcutaneous tissue and the joint capsule for all cases.

#### ***Hydrogen Peroxide***

Hydrogen peroxide [19] has been used for decades as an effervescent haemostatic agent in arthroplasty (especially during cemented total hip arthroplasty) to

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achieve a dry bony surface prior to cementing. We have used the same principle in all knees to achieve the soft tissue haemostasis. After final implantation and prior to wound closure, the wounds were alternately packed with hydrogen peroxide and Feracrylum for three minutes while waiting for the cement to set.

### ***Feracrylum***

Feracrylum was used for all patients in our series to decrease blood loss. Feracrylum [20,21] has a wide therapeutic application as a haemostatic agent to decrease postoperative oozing. Feracrylum has a unique property of reacting with proteins including those present in blood to form an insoluble poly-complex. This property is primarily responsible for its pharmacotherapeutic utility. It reacts mainly with albumin and converts soluble fibrinogen to insoluble fibrin which then forms a coagulum. This arrests bleeding and oozing from highly vascularized tissues. The mean time for formation of this coagulum is 30 sec. Feracrylum is very effective especially against bleeding from capillaries and venules. Because of its novel mechanism of action i.e. not involving the coagulation pathway, it is useful in patients with coagulation disturbances undergoing surgery. We accept that although Feracrylum is commonly used in our part of the world, there is not enough literature to support its use.

### ***Tranexamic Acid***

Tranexamic acid (1, 4- amino- carboxylic acid) is an antifibrinolytic agent which is seven to ten times as potent as epsilon aminocaproic acid (EACA). Tranexamic acid is a synthetic derivative of the amino acid lysine that exerts its antifibrinolytic effect through the reversible blockade of lysine-binding sites on plasminogen molecules [32-34]. As tranexamic acid enters the extravascular space and accumulates in tissues for up to 17 hours, the basis for its mechanism of action is thought to be inhibition of tissue fibrinolysis and consequent stabilization of clots [35].

Tranexamic acid, a synthetic fibrinolytic inhibitor, has been used for more than 20 years in various fields such as dentistry, gynaecology, cardiac surgery, urological surgery, and liver transplantation. Multiple studies have shown that tranexamic acid can reduce blood loss and decrease the need for red blood cell transfusions in patients undergoing primary total knee arthroplasty [5,10,11,12,36-52].

Yamasaki and colleagues [53] demonstrated that tranexamic acid reduced total blood loss primarily by reducing the blood loss during the first two hours after surgery. The fibrinolytic response after trauma is biphasic with an increased activity during the first few hours, followed by a shutdown that peaks at about 24 hours. After knee arthroplasty, the early post-traumatic fibrinolysis is further augmented by that induced by the tourniquet [54]. Given that the mean duration of effect of tranexamic acid is around 3 hours, a second dose was administered after this period to prolong the effect over the first 6 hours, when 60% to 80% of the blood loss (including the hidden loss) occurs. Hence, our current dosage seems to be an adequate compromise between fibrinolytic inhibition and the risk of inducing an augmented fibrinolytic shutdown.

Our findings of reduced postoperative bleeding are consistent and comparable with the findings of previous meta-analyses of individual studies of intravenous tranexamic acid administration in patients undergoing total knee arthroplasty, which demonstrated a reduction of blood loss of about 400 mL per case [47,55,56]. The reduction in blood loss in our study is in accordance with other studies [5,12,57] that have reported a 45–54% reduction. Tanaka and colleagues [38] have demonstrated a 40–58% decrease in blood loss when tranexamic acid was given preoperatively and intraoperatively.

A theoretical concern associated with the use of tranexamic acid is its potential for inducing thromboembolic events [38,55,58]. However, the use of tranexamic acid does not seem to cause any higher incidence of deep venous thrombosis [11,12,34,37,38]. Tanaka and colleagues [38] found there was no increase in deep-vein thromboses or pulmonary emboli on the basis of radioisotope venography and lung scanning in patients receiving intravenous tranexamic acid. Orpen and colleagues [43] reported that no deep-vein thromboses were detected with duplex ultrasound scanning. The reports by Alvarez and colleagues [45] and Kagoma and colleagues [47] suggest tranexamic acid does not result in an increase in thrombo-embolic events. Lozano and colleagues [46] have also reported that the use of tranexamic acid was not associated with an increase in thrombotic complications either clinically or as documented by contrast venography.

In our clinical study, one patient developed cerebral thromboembolism, who on retrospective evaluation revealed a history of similar episode in the past



from which he had recovered completely. Although thromboembolism has been reported in other studies, the authors of those studies were unable to determine whether thromboembolism resulted from the administration of tranexamic acid or other variable associated with total hip or knee arthroplasty. The use of tranexamic acid is contraindicated in patients with a history of thromboembolic disease and renal failure [5,11,34,37,58,59,60].

### ***Use of Pneumatic Tourniquet***

The use of pneumatic tourniquet does not reduce the blood loss and it may even increase it [18,61,62]. A prolonged tourniquet time may induce a post-ischemic reperfusion injury resulting in reactive hyperaemia and edema [63]. It may also stimulate fibrinolysis and increase the hidden blood loss [63]. We have not used tourniquet in any of our cases in the present series.

### ***Nonpharmacologic Prophylaxis***

In our series, none of the patients received any pharmacologic prophylaxis against venous thromboembolism but TED stockings were utilized postoperatively for 6 weeks. We believe the addition of pharmacologic prophylaxis would probably not affect the overall results although this is a conjecture. The lead author of this paper (N.A.S.) has used aspirin extensively as a form of DVT prophylaxis in his practice, although being aware that some surgeons do not prefer the use of aspirin. Moreover, the authors believe that since a tourniquet is not used during the operative procedure, the rate of DVT is extremely low. The authors are currently undertaking a detailed study looking specifically at DVT rates using the protocol described in this paper.

### ***Avoidance of Surgical Wound Drainage***

The avoidance of closed suction drainage reduces the external blood loss, but not necessarily the hidden loss, which may be increased, particularly after total knee replacement [64]. However, the overall balance appears to be towards a reduction in total blood loss [18,65].

### ***Relationship Between Operating Time and Intraoperative Blood Loss***

There have been few reports that have described the relationship between operative time and intraoperative blood loss. Salido and colleagues [66] showed a significant relationship between the opera-

tive time and the need for postoperative blood transfusion. In the study by Ekbäck and colleagues, [59] the operative time was 120 minutes. In our series, the average duration of surgery was around 90 to 100 minutes. None of the patients in our series required a blood transfusion.

### ***Limitations of Our Study***

The present study has few limitations.

(1). Our study involved a consecutive series of 150 patients. This is a non-randomized study. There is no control group.

(2). Our series is a cohort study. A retrospective analysis of a prospectively collected data was performed. Power calculation was not performed from the outset to examine the assumption that tranexamic acid can decrease the frequency of allogeneic blood transfusion, although none of the patients in our series required a blood transfusion.

(3). We used the mean reduction in hemoglobin as a surrogate marker for blood loss. We acknowledge that other factors may have led to a reduction in the mean hemoglobin, such as hemodilution from perioperative fluid resuscitation and the type of anesthetic used.

(4). We did not perform routine screening for deep-vein thromboses and pulmonary emboli; however, based on physical examination, no significant thrombo-embolic complications were noted in our series during the six-week follow-up period.

(5). This study has not addressed the subjective knee function score and objective clinical examination findings of the patients after total knee arthroplasty. Our main purpose of this paper was to report our operative technique strategies to minimize the perioperative blood loss in patients who undergo total knee replacement.

One advantage of our study is that it compares a prospective cohort of patients operated on by the same surgeon who used the same operative approach and surgical technique for all 150 cases in our series. Moreover, the same postoperative rehabilitation protocol was used for all patients.

Our study is unique as we believe there is an additive effect of various blood conserving measures that were used in our series. We believe a blood transfusion can be avoided if blood loss is minimized using our suggested blood conserving strategies. Our study reports the least hemoglobin fall after a TKR in the literature and allows us to do a TKR without the requirement of any blood transfusion.

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## Conclusions

Combined effectiveness of regional anaesthesia, mini-subvastus approach, use of saline-adrenaline infiltration, hydrogen peroxide and Feracrylum-soaked packs, perioperative use of tranexamic acid, without using tourniquet and drains, reduces perioperative bleeding in patients undergoing total knee replacement, thereby reducing the blood transfusion requirement in these patients to almost negligible amount (as none of our patient required blood transfusion in the current series). Moreover, the treatment cost is low, and safety has proved to be high, there being no increased risk of thromboembolic complications in properly selected patients.

Larger prospective, randomized clinical trials are needed to further assess the safety and efficacy of our promising strategy to reduce bleeding and the need for allogeneic blood transfusion in patients undergoing total knee arthroplasty.

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# Early Results of a Modular Revision System in Total Knee Arthroplasty

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## Abstract

**Background:** The number of revision total knee arthroplasty (TKA) procedures is projected to rise dramatically over the next fifteen years. These procedures are technically more demanding than routine primary TKA. Modular component options can assist the surgeon in addressing complex reconstructions in TKA, providing customization to remedy bony deficits, deformity, malalignment and instability. We review the early clinical results of a modular revision system that offers full interchangeability enhanced with a wide array of options for augmentation, offset, and constraint as well as modular stems.

**Materials and Methods:** A query of our practice's arthroplasty registry revealed a consecutive series of 100 patients (101 knees) who signed an IRB-approved general research consent allowing retrospective review, and underwent total knee arthroplasty performed with the modular revision system between May 2011 and May 2012. Reconstruction constructs and components, demographic variables, pre and post-operative clinical variables, failure modes, and survivorship were analyzed.

**Results:** At an average follow-up of 1 year (range, 0.1 to 2.2 years) there has been one aseptic failure for instability. One patient required incision and debridement of a non-healing wound. Three patients, all status-post reimplantation, failed secondary to recurrent infection, with one treated single-staged and the others undergoing another 2-staged exchange. Average ROM improved from 96.4° preoperatively to 104.8° at most recent evaluation. Average Knee Society clinical scores (0 to 100 possible) improved from 45.5 to 78.0, and function scores (0 to 100 possible) improved from 41.3 to 48.3. There have been no patient deaths during the follow-up period. Postoperative radiographs were available for review for 97 knees. Satisfactory position, fixation and alignment were observed in 92 (95%). Heterotopic ossification was observed at the lateral tibial aspect in 1 knee with CR lipped bearing. A stable radiolucency was observed around the tibial component of one knee. Minor radiolucencies were observed in femoral zones I and II and tibial zone 1 on lateral view of one knee, in tibial zones III and IV on AP view in one knee, and in tibial zone IV on AP view in one knee.

**Conclusion:** The early results of this modular TKA revision system are promising for use in complex TKA, with only one aseptic failure observed. There has been substantial improvements in ROM and function in this cohort.

**Key words:** *Arthroplasty, Knee, Revision*



## Introduction

Total knee arthroplasty (TKA) is a common procedure with great clinical success and 95% survivorship at 15 years as reported by multiple authors [1,2]. Annual rates of primary TKA are increasing, and projections for revision TKA are expected to rise 601% by the year 2030 [3]. There are significant technical challenges with revision TKA, including bone loss, deformity, malalignment, and instability coupled with a higher rate of both surgical and medical complications. The aim of this study was to investigate the early results of a fully interchangeable, modular revision knee system with a wide array of implant system options for sizing, stems, augmentation, offset, and constraint, designed to address the technical demands of revision surgery.

## Materials and Methods

A retrospective investigation of our practice's arthroplasty database registry identified a consecutive series of 100 patients (101 knees) between May 2011 and May 2012 who underwent revision TKA with a modular revision knee system (Vanguard SSK 360, Biomet, Inc., Warsaw, IN, USA). A signed institutional review board (IRB) approved general research consent allowing retrospective review was obtained from all patients. The database was reviewed to analyze component constructs and level of constraint, demographic variables and preoperative and postoperative clinical assessment data including Knee Society scores, range of motion, limb alignment, indication for revision, and survivorship. Postoperative radiographs were reviewed in 97 knees.

There were 41 men and 59 women. Age averaged 64.2 years (range, 33-90) and BMI averaged 34.7 kg.m<sup>2</sup> (range, 20-67). Procedures were revision of unicompartmental to total in 3 knees, revision in 69 (68%), and reimplantation after 2-stage treatment of infection in 29 (29%). Non-infectious indications for revision included aseptic loosening in 30 knees, instability in 38 knees, arthrofibrosis in 10 knees, periprosthetic fracture in 2, and malalignment in 2.

Two knees had no revision performed on the femoral side while 3 were revised to a cruciate retaining femoral component mated to the modular revision tibial component. Seven knees had no revision of the tibial component, while one was revised to a primary fixed I-beam tibial component mated with the modu-

lar revision femoral. The tibial inserts utilized were standard cruciate-retaining (CR) in one, CR-lipped in one, ultracongruent anterior stabilized in 3, non-constrained posterior-stabilized in 12 and varus-valgus constrained in 84 (84%). Offset adapters were used with 42 femoral components and 28 tibial components. Average femoral and tibial offset, when utilized, was 4.8 and 4.7mm, respectively. A cruciate wing was added to 19 tibial components. Femoral and tibial stems were utilized in 96 and 91 knees, respectively. Femoral stems were 97% splined and with lengths of 40mm (n=6), 80mm (n=37), 120mm (n=45), 160mm (n=6), and 200mm (n=2). Tibial stems were 94% splined and with lengths of 40mm (n=3), 80mm (n=32), 120mm (n=56), and 160mm (n=3). Femoral augments were utilized in 52 cases and porous metal femoral augments in an additional 9 cases. Tibial augments were used in 26 cases and porous metal tibial augments in an additional 9 cases.

## Results

Clinical outcomes improved significantly after the revision TKA compared with preoperative levels (Figure 1). At an average follow-up of 1 year (range, 0.1 to 2.2 years), range of motion improved from 96 degrees preoperatively to 105 degrees postoperatively. Knee Society clinical scores (range 0 to 100 possible) improved from 45.4 to 78.0, and function scores (0 to 100 possible) improved from 41.2 to 48.4.

One patient required incision and debridement of a non-healing wound. Three patients, all status-post reimplantation, failed secondary to recurrent infection, with one treated single-staged and the others undergoing another 2-stage treatment. One patient required polyethylene exchange for instability (polyethylene thickness increased 4mm). There have been no patient deaths during the follow-up period.

Postoperative radiographs were available for review for 98 knees. Satisfactory position, fixation and alignment was observed in 93 (95%). Heterotopic ossification was observed at the lateral tibial aspect in 1 knee with CR lipped bearing. A stable radiolucency was observed around the tibial component of one knee. Minor radiolucencies were observed in femoral zones I and II and tibial zone 1 on lateral view of one knee, in tibial zones III and IV on AP view in one knee, and in tibial zone IV on AP view in one knee.



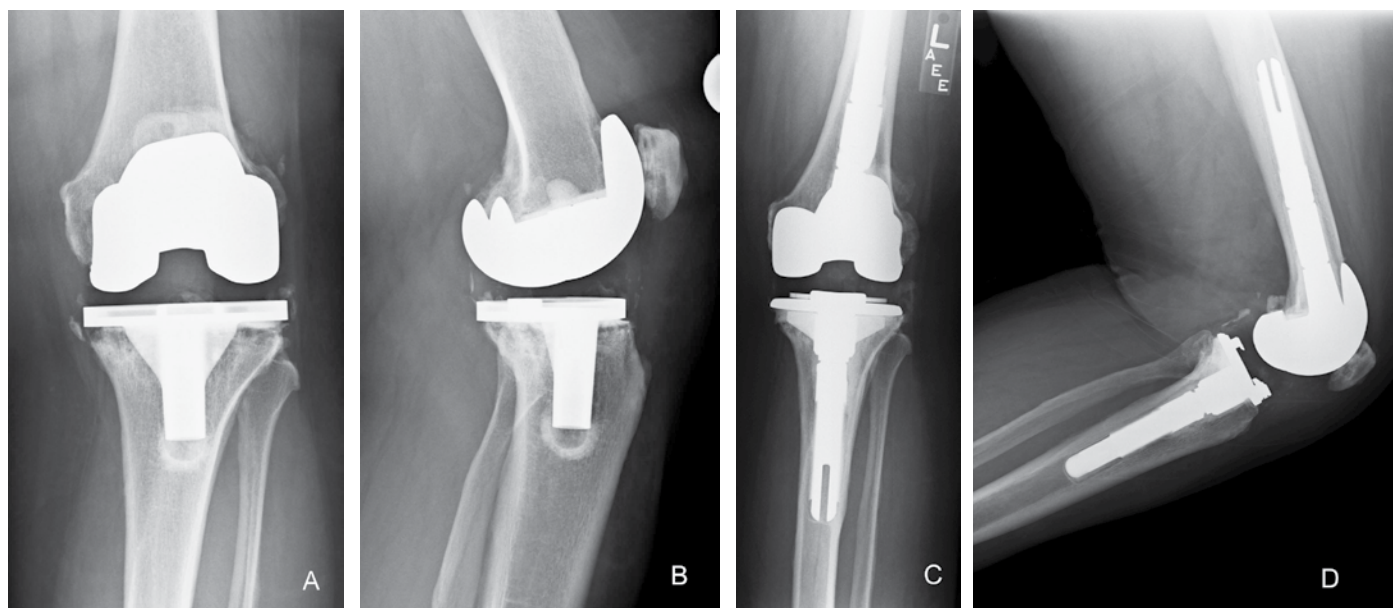


Figure 1. A 68-year-old female patient presented with moderate left knee pain and instability 10 years after undergoing primary total knee arthroplasty with a cemented, posterior-stabilized device. Preoperative anteroposterior (A) and lateral (B) radiographs demonstrate aseptic loosening and tibiofemoral alignment of 8° varus. Anteroposterior (C) and lateral (D) radiographs at 2 years postoperative demonstrate well-fixed components in satisfactory position and alignment. Patient has been treated with left cemented revision TKA using a 62.5mm component with 10mm posterior augment, 2.5mm offset adaptor and 16x80mm splined stem on the femoral side, and 67mm tray with 16x63/67mm constrained insert, 16x80 splined stem, and small cruciate wing on the tibial side. The patellar component was not revised. Her Knee Society clinical score is 99 and function score is 50.

## Discussion

The revision burden for TKA is increasing annually. Unfortunately, failure of revision TKA is not uncommon with some authors reporting rates as high as 63% within the first 5 years, predominately due to infection, instability, loosening, and patellofemoral problems [4]. These etiologies are also common in late failures, although polyethylene wear and aseptic loosening of cemented components predominates [5]. Additional risk factors for failure include younger age at the time of index arthroplasty, coronal malalignment, elevated body mass index, and lower socioeconomic and educational status [6]. Despite the various failure modes, the goal of revision arthroplasty, similarly to primary TKA, is to reduce pain and improve function. Revision TKA has been shown to be successful in improving patient outcomes in a cost-effective manner, however, in comparison to primary TKA, it is more expensive, has a higher complication rate, and has lower quality of life outcome scores [7-9].

Revision TKA is technically demanding and is potentially complicated by multiple factors not present during primary TKA including the need to remove components, sepsis, scarring and arthrofibrosis, ligamentous insufficiency or compromise, bone defects, metallic and polyethylene wear debris with variable

levels of osteolysis, and deformity. Modern revision TKA systems offer a high degree of modularity, offset, metallic augmentation, stem lengths and fixation methods, and degree of constraint (Table 1). The revision knee system evaluated in this study addresses these needs with a comprehensive interchangeability between femoral and tibial sizes, 360 degrees of femoral and tibial offset options to allow for component position optimization for the best load transfer, a high degree of varus/valgus constraint without the use of a hinged prosthesis, and a simplified trial first approach to revision to provide for a more efficient surgery. The early results of this retrospective database review are promising, with improvement in pain and functional scores with only one failure for aseptic means at early follow-up. Continued monitoring of this cohort is paramount to analyze mid-term and long-term results.

## Conclusion

The early results of this modular TKA revision system are promising for use in complex TKA, with only one aseptic failure observed. There has been substantial improvements in ROM and function in this cohort.

**Table 1. Results of Constrained Total Knee Arthroplasty**

Study	Number of Knees	Device	Description	Follow-up (years)	Survival
Donaldson III et al., CORR 1988 [10]	31	TC III	17 Primary, 14 Revision	3.8	80.6%
Chotivichit et al., J Arth 1991 [11]	27	TC III	9 Primary, 18 Revision	4.3	100%
Hohl et al., CORR 1991 [12]	61	TC III	Complex Primary & Revision	6.1	95.1%
Kavolus et al., J Arth 1991 [13]	16	TC III	5 Primary, 16 Revision	4.5	100%
Rand, J Arth 1991 [14]	21	TC III	Revision, severely damaged knees	4	85.7%
Rosenberg et al., CORR 1991 [15]	36	TC III	Revision	3.8	97.2%
Stern et al., CORR 1991 [16]	8	NA	Primary, valgus $\geq 10^\circ$	4.5	100%
Haas et al., JBJS Am 1995 [17]	19	IB CCK	Revision, uncemented stems	3.6	89%
Vince & Long, CORR 1995 [18]	13	IB CCK	Revision	6	75%
Lachiewicz & Falatyn, J Arth 1996 [19]	46	TC III & Constrained Condylar	25 Primary, 21 Revision	46	95.7%
Lombardi et al., Seminars in Arthroplasty 1996 [20]	66	Maxim PSC	Revision	2	92.4%
Font-Rodriguez et al., CORR 1997 [21]	64	Constrained Condylar	Primary, cemented	7	98.1%
Peters et al., J Arth 1997 [22]	43	TC III, Constrained Condylar, Maxim PSC	Revision, cemented	5.2	97.7%
Hartford et al., J Arth 1998 [23]	33	TC III	17 Primary, 16 Revision, 8 Reimplantation	5	91%
Easley et al., CORR 2000 [24]	44	IB CCK	Primary for valgus deformity	7.8	100%
Nazarian et al., CORR 2002 [25]	207	IB CCK	Revision, 55 no stems	4.7	92.8%
Sheng et al., JBJS Br 2005 [26]	16	TC III	Revision, inflammatory	6.2	81.3%
Anderson et al., CORR 2006 [27]	55	Optetrak CCK	Primary without stems for valgus deformity	3.6	100%
Berend et al., CORR 2006 [28]	5	Maxim PSC	Primary, flexion contracture $>20^\circ$	3.1	100%
Lachiewicz & Soileau, J Arth 2006 [29]	54	IB CCK & TC III	Primary	10	96%
Lombardi & Berend, Orthopedics 2006 [30]	421	Maxim PSC	47 Primary, 284 Revision, 90 Reimplantation	5	88.6%
Sheng et al., Acta Orth 2006 [31]	71	TC III	Revision	5.9	91.5%
Anderson et al., J Knee Surg 2007 [32]	248	Optetrak CCK	Primary without stems	3.9	97.5%
Lombardi et al., JBJS Am 2007 [33]	61	Maxim PSC	Complex Primary	5.6	88.5%
Kim & Kim, JBJS 2009 [34]	114	LCCK	Revision	7.2	96%
Peters et al., J Arth 2009 [35]	184	Maxim PSC & Vanguard PSC	Revision, cemented with cementless stems	4.1	91.8%
Hwang et al., COS 2010 [36]	25	LCCK	Revision, cemented	2.5	100%
Lachiewicz & Soileau, J Arth 2011 [37]	27	LCCK	Primary	5.4	96%
Lee et al., KSSTA 2013 [38]	79	LCCK	Revision	5.3	89.9%
Lee et al., J Arth 2013 [39]	27	LCCK with PS insert	Revision	7.0	100%
Pang et al., KSSTA 2013 [40]	50	LCCK & PFC Sigma TC III	Primary, type II valgus	8.3	96%

TCIII = Total Condylar III (Depuy, a Johnson & Johnson company, Warsaw, IN); NA = not available; IB CCK = Insall-Burstein Constrained Condylar Knee (Zimmer, Warsaw, IN); Constrained Condylar (Zimmer); Maxim PSC = Maxim Posterior Stabilized Constrained (Biomet, Warsaw, IN); Optetrak CCK = Optetrak Constrained Condylar Knee (Exactech, Gainesville, FL); Vanguard PSC = Vanguard Posterior Stabilized Constrained (Biomet); LCCK = Legacy Constrained Condylar Knee (Zimmer); PFC Sigma = Press-Fit Condylar Sigma (DePuy).

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# Modular Femoral Tapered Revision Stems in Total Hip Arthroplasty

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## Abstract

**Background:** Modular component options can assist the surgeon in addressing complex femoral reconstructions in total hip arthroplasty by allowing for customization of version control and proximal to distal sizing. We review the early clinical results of a single modular femoral revision system that offers 3 proximal body types, 5 distal stem geometries, and a wide range of offset, sizing and auxiliary options.

**Methods:** A query of our practice's arthroplasty registry revealed 60 patients (61 hips) who signed an IRB-approved general research consent allowing retrospective review, and underwent total hip arthroplasty performed with the modular femoral revision system between December 2009 and April 2012. There were 35 men (58%) and 25 women (42%). Mean age was 65.1 years (range, 35-94) and BMI was 31.3 kg.m<sup>2</sup> (range, 14-53). Procedures were complex primary in 1 hip, conversion in 6 (10%), revision in 32 (53%), and two-staged exchange for infection in 22 (33%). Two-thirds of procedures included complete acetabular revision (n=40), while 31% (19) involved liner change only and 2 were isolated femoral revisions.

**Results:** At an average follow-up of 1.5 years (maximum: 3.7 years) there have been no revisions or failures of the femoral component. Average Harris hip scores (0 to 100 possible) improved from 44.2 preoperatively to 66.0 at most recent evaluation, while the pain component (0 to 44 possible) improved from 15.8 to 31.2. Complications requiring surgical intervention included intraoperative periprosthetic femur fracture in one patient returned to the operating suite same day for open reduction internal fixation, which further required incision and debridement for super-

ficial infection at 1 year postoperative; and two patients with dislocation and fracture of the greater trochanter treated with open reduction, revision of the head and liner, and application of cerclage cables, one of which required removal of a migrated claw 10 months later followed 2 weeks subsequently with incision and debridement for a non-healing wound. Postoperative radiographs were available for review for 59 THA in 58 patients. Analysis of the femoral component revealed satisfactory findings in 50 hips (85%) while 9 had radiographic changes that included bone deficit, osteolysis, or radiolucency in one or more zones.

**Conclusions:** The early results of this modular femoral revision system are promising for the treatment of the deficient femur in complex primary and revision total hip arthroplasty. Patients with radiographic changes are advised to return for regular clinical and radiographic follow-up. Survival of the modular femoral component in this series was 100% at mean follow-up of 1.5 years and up to 3.7 years. While HHS clinical and pain scores were somewhat low at most recent evaluation, they were significantly improved over preoperative levels.

## Introduction

The primary goals of revision hip surgery are pain

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relief and long term stable implant fixation. Femoral bone stock in revision arthroplasty is commonly compromised by osteolysis, stress shielding, and iatrogenic damage from implant removal and sometimes multiple revision surgeries. The proximal bone is typically deficient and cannot support stems that rely on proximal fit and fill. This had led to the development of diaphyseal engaging stems that load the diaphysis and bypass the deficient proximal femur. These include monoblock extensively porous coated stems, monoblock fluted tapered stems, and more recently modular fluted tapered stems.

Other common challenges in femoral revision include expansion of cortices, varus remodeling, leg length discrepancy and instability. These challenging situations can make the attainment of stable implant fixation while maintaining hip stability difficult with monoblock stems. Modular stems allow surgeons to establish stable diaphyseal fixation while attaining appropriate leg length and hip stability independently. The authors currently utilize a modular fluted tapered stem for the majority of femoral revisions.

The indications for a modular tapered stem depend on the amount of bone loss and surgeon philosophy. Some surgeons including the authors use this style of implant for the majority of femoral revisions due to the ease of implantation and versatility of the modular design. Some surgeons prefer proximal loading stems for Paprosky Type 1 [1] (Table 1) and Mallory Type 1 [2] (Table 2) femurs with an intact proximal metaphysis. Others may choose extensively porous coated stems for Paprosky Type 2 and 3A and Mallory Type 2 femurs that have intact diaphy-

seal bone or an isthmus of at least 4 cm for a good scratch fit. Modular tapered stems are recommended by the authors and others for severe diaphyseal bone loss including Paprosky Type 3A femurs with a diameter greater than 19 mm or Paprosky Type 3B femurs with an isthmus less than 4 cm. These situations have shown unsatisfactory failure rates with extensively porous coated stems [1]. Some surgeons have had success with modular tapered stems in Paprosky Type 4 femurs with extensive loss of diaphyseal bone however this stem is contraindicated when stable fixation of the implant is unachievable. Megaprotheses and impaction grafting with cemented stems are other options in this situation. Periprosthetic fractures requiring femoral component revision are effectively treated with modular tapered stems. After exposure and implant removal, the diaphyseal femur can be prepared with tapered reamers and a stable stem can be implanted. The appropriate proximal body is then selected to restore leg length and stability. The fracture fragments can then be reduced around the stem and secured with cables.

Heinz Wagner developed a monoblock titanium grit blasted fluted tapered stem. The diaphysis is prepared with tapered reamers until a secure fit is obtained. Engaging the tapered stem into the prepared diaphysis provides axial stability for the implant. Rotational stability is provided by sharp flutes. The grit blasted surface allows for biological fixation and the titanium substrate provides a modulus of elasticity closer to that of bone than cobalt-chromium alloys. This concept may have the advantage of less stress-shielding than fully porous coated cobalt-chromium stems. Modern stem designs are based on this philosophy and have added modular proximal bodies to make the stem more versatile in challenging revision cases. After the tapered stem is secured in the diaphysis the remaining proximal femur is prepared to accept the appropriate sized proximal body. The proximal body that appropriately restores leg length, anteversion, offset and hip stability is attached to the upper portion of the stem. Multiple proximal body geometries are offered by different vendors. A cone proximal body is versatile in allowing customization of version during surgery. A tapered body can allow loading of the proximal femur within the metaphysis. A calcar body also allows loading of the proximal femur via platform loading of the remaining medial supportive bone. The major concern for this type of design is an unsupported taper junction that can be weakened by repetitive stresses. Fractures at

**Table 1.** Paprosky classification of femoral defects [1]

Type	Description
1	Minimal defects, similar to primary total hip arthroplasty
2	Metaphyseal damage, minimal diaphyseal damage
3A	Metadiaphyseal bone loss, 4 cm scratch-fit can be obtained at isthmus
3B	Metadiaphyseal bone loss, 4 cm scratch-fit cannot be obtained
4	Extensive metadiaphyseal damage, thin cortices, widened canals

**Table 2.** Mallory classification of femoral defects [2]

Type	Description
1	Cortical tube intact, cancellous bone is present
2	Cortical tube intact, cancellous bone is present
3A	Cortical tube intact, cancellous bone is present
3B	Cortical deficiency extending to between lesser trochanter and isthmus
3C	Cortical deficiency extending to between lesser trochanter and isthmus

the modular junction are reported in the literature on multiple stem designs [3-7]. Manufacturers have developed methods for strengthening the taper junction. The authors currently use a stem design that has undergone a proprietary process of roller-hardening of the taper junction (Biomet, Inc., Warsaw, IN), which according to the manufacturer provides up to three times more strength in cantilever beam testing. We review the indications, surgical techniques utilized, early clinical results and survival of a consecutive series of patients undergoing revision THA performed using single modular femoral revision system that offers 3 proximal body types, 5 distal stem geometries, and a wide range of offset, sizing and auxiliary options.

## Methods

A query of our practice's arthroplasty registry revealed 60 patients (61 hips) who signed an IRB-approved general research consent allowing retrospective review, and underwent total hip arthroplasty performed with a modular femoral revision system (Figure 1; Arcos Modular Revision Hip System; Biomet, Inc., Warsaw, Indiana, USA) between December 2009 and April 2012. There were 35 men (58%) and 25 women (42%). Mean age was 65.1 years (range, 35-94) and BMI was 31.3 kg.m<sup>2</sup> (range, 14-53). Procedures were conversion in 7 (11%), revision in 32 (53%), and two-staged exchange for infection in 22 (33%). Underlying diagnoses for conversion cases were Crowe III developmental dysplasia previously treated with multiple surgeries including osteotomies of the pelvis and femur in one, failed hemiarthroplasty due to femoral loosening in two and periprosthetic femoral fracture in one, and failed open reduction internal fixation of fracture secondary to non-union in three. For revision cases, underlying diagnoses were aseptic loosening in 27, periprosthetic femoral fracture in two, and one each component breakage, failed open reduction internal fixation (ORIF) of fracture secondary to non-union, and instability with insufficient femoral offset. Preoperative femoral deformities according to the Mallory classification were Type 2 in 7 hips (11.5%), Type 3A in 10 (16.4%), and 22 each (36.1%) of 3B and 3C. The planning process begins with a detail history and physical exam as well as appropriate radiographs. All revision cases must have an evaluation to rule out periprosthetic joint infection. Radiographs are examined to determine the extent of femoral os-



Figure 1. The modular, tapered titanium revision hip system used in the current study (Arcos, Biomet) features three proximal body types and five distal stem geometries with a wide range of sizes, offsets, and auxiliary options. (Photo reproduced courtesy of Biomet).

teolysis, cortical perforations, proximal deformity, cement mantles, and the need for a femoral osteotomy. Templating can be performed to determine the planned stem length and diameter as well as proximal body size and offset.

The surgical approach for femoral revision depends on multiple factors including surgeon preference and experience, type of stem being revised, associated bone loss, and whether acetabular revision is required. A proximal femoral osteotomy may be required depending on fixation of the existing stem and associated proximal femoral deformity. The authors preferred exposure is via an anterolateral abductor splitting approach. The vastus lateralis along with the anterior third of the gluteus medius and minimus are elevated as a continuous soft tissue sleeve from the anterior femur. If a proximal femoral osteotomy is required, the authors prefer either a Wagner transfemoral osteotomy or an anterior extended trochanteric osteotomy (ETO). These anterior based osteotomies provide excellent access to the existing stem as well as remaining cement mantles after cemented stem removal. Another advantage of an anterior based osteotomy is that it allows the surgeon to

prepare the canal with straight tapered reamers while avoiding perforation of the anteriorly bowed femur.

Once the previous stem and any remaining cement mantle are removed the surgeon begins preparing the femur with straight tapered reamers. Reaming proceeds until good engagement of the reamer is obtained. The authors prefer to use a hand reaming technique as to gain the appropriate tactile feel of the reaming. Insufficient reaming may lead to subsidence of the implant and over-reaming will remove excess bone leading to weakening of the diaphysis and possible fracture or perforation. Inspection of the reamers provides feedback to how much bone is being removed. Care is taken to make sure the reamers are advancing straight down the shaft of the femur. Fluoroscopy may be used with long reamers to monitor for perforation or to verify the surgeon has bypassed any cortical defects. Most implant systems have markings on the reamers to judge depth based on the tip of the greater trochanter. Once adequate depth and size of reaming is achieved either a trial or final tapered stem is implanted into the diaphysis. If a femoral osteotomy was performed a prophylactic cable is placed distal to the osteotomy before stem insertion. This will help resist the high hoop stresses in this area which can fracture the femur. Longer stems will usually have a bow just proximal to the flutes and tapered region to accommodate for the anterior bow of the femur. The implant is driven into the femur with moderate taps of the mallet until it ceases to advance. The proximal femur is then prepared with implant specific reamers to accept the largest possible diameter proximal body. Trial proximal bodies are placed on the distal stem until the appropriate length, offset and anteversion are determined. The actual selected proximal body is then placed on the distal stem in the desired position determined by trialing and secured according to the vendor's specifications. The hip is then reduced with the appropriate size femoral head. If an extended trochanteric osteotomy was performed the fragment can now be reduced and secured to the femur with cables. A burr is used to shape the undersurface of the fragment if it does not fit ideally against the femur with the prosthesis in place.

The main intraoperative complications specific to modular tapered stems are femoral perforation and fracture during reaming and implantation. As described above, an anteriorly based proximal femoral osteotomy and reaming under fluoroscopy can decrease the risk of perforating the anterior cortex due

to the femoral bow. A prophylactic cable distal to the femoral osteotomy will help resist high hoop stresses in this area which could result in fracture.

Postoperative complications specific to this type of stem are implant subsidence and fracture at the modular junction. As described above, hand reaming the canal allows the surgeon to have tactile feel of the reamer engaging the diaphysis. This technique aids in achieving an adequate ream to prevent subsidence while not removing excessive bone. Fluoroscopy can also be used to evaluate the size of the last reamer in relation to the size and shape of the canal. Manufacturers have made modifications to the modular junction to prevent the risk of fracture. Despite these modifications, femurs with complete loss of proximal bone will leave the modular junction unsupported and at risk for fracture. These cases may be better treated with a proximal femoral replacement.

Postoperatively, patients were typically placed on weight bearing restrictions for 6 weeks and then progressed according to the level of healing and complexity of revision. Patients were evaluated at 6 weeks, 1 year, and annually thereafter with clinical assessment including the Harris hip score (HHS) [8]. Radiographs obtained at each visit included standing anteroposterior (AP) pelvis, lateral and additional AP view of the affected hip. The femoral component was assessed using the zones of Gruen [9], noting presence of bone deficits, osteolysis, radiolucency, hypertrophy of the femoral shaft, heterotopic ossification according to the Brooker classification [10], stem subsidence or migration, healing of the greater trochanter, healing of fracture site, radiolucencies about and fixation of ORIF device.

## Results

The surgical approach was the anterolateral abductor splitting in all cases, with femoral osteotomy required in 25 (41%). Of those two were a simple episiotomy, 3 were Wagner transfemoral, and 20 were the anterior extended trochanteric. Proximal type femoral component bodies used were cone in 54 (89%), broached in 6 (10%), and calcar in one. Proximal component diameters used were 18.5mm (A) in 20 (33%), 20.5mm in 13 (21%), 22.5mm (C) in 10 (16%), 24.5mm (D) in 14 (23%), and 26.5mm (E) in 4 (7%). A 28.5mm diameter (F) is also available. Standard offset proximal bodies were used in 25 hips (41%), while high offset bodies with an add-

ed 6mm horizontally were used in 34 (56%). Distal femoral stems were straight tapered splined (STS) in 55 (90%), bowed STS in 5 (8%), and bowed interlocking distal porous coated in one. Distal diameters utilized ranged from 12- to 25mm, with 15mm being used most frequently (12; 20%). Distal stem lengths utilized were 150mm in 28 hips (45%), 190mm in 27 (44%), 250mm in 5, and 300mm in one. Femoral fixation was augmented by use of cables in 34 hips (56%), a trochanteric grip or plate in 9 (15%), strut allografts in 4 (7%), and crushed cancellous or bone graft substitute in 11 (18%).

Two-thirds of procedures included complete acetabular revision (n=40), while 31% (19) involved liner change only and 2 were isolated femoral revisions. Acetabular components utilized were one custom triflange based on preoperative imaging, one cemented all-polyethylene constrained, 5 standard porous hemispheric, and 33 ultraporous metal. Constrained liners were used in a total of 11 hips including the aforementioned all-polyethylene, and dual mobility devices were used in three. Porous metal augments were used in 2 cases including one posterior column buttress and one further reinforced with impaction grafting. Impacted crushed cancellous allograft was used in 6 additional acetabular reconstructions, bone graft substitute was used to fill cavitary defects in one, and femoral head autograft fixed with 2 cortical screws was used to fill a superior defect in the case of severe dysplasia.

At an average follow-up of 1.5 years (maximum: 3.7 years) there have been no revisions or failures of the femoral component. Five patients died during the study period, with 2 deaths occurring within 90 days of the index procedure. One was an 88-year-old female with BMI of 14.3 kg/m<sup>2</sup> who fell and sustained a Vancouver B3 periprosthetic fracture. The other was a 67-year-old male patient undergoing treatment for liver cancer who was revised for gross loosening with impending fracture of a cemented stem. Both patients had returned for their 6-week follow-up visit.

Average Harris hip scores (0 to 100 possible) improved from 44.2 preoperatively to 66.0 at most recent evaluation, while the pain component (0 to 44 possible) improved from 15.8 to 31.2. Complications requiring surgical intervention included intraoperative periprosthetic femur fracture in one patient returned to the operating suite same day for ORIF, which further required incision and debridement for superficial infection at 1 year postoperative; and two

patients with dislocation and fracture of the greater trochanter treated with open reduction, revision of the head and liner, and application of cerclage cables, one of which required removal of a migrated claw 10 months later followed 2 weeks subsequently with incision and debridement for a non-healing wound.

Postoperative radiographs were available for review for 59 THA in 58 patients. Analysis of the femoral component revealed satisfactory fixation and alignment in 57 hips (97%) with evidence of bone maintenance and healing of osteotomies and fracture sites. Brooker III heterotopic ossification was evident in one hip. Two hips showed evidence of proximal bone loss or radiolucency in one or more zones, but had healing of osteotomy sites. None showed evidence of loosening or subsidence.

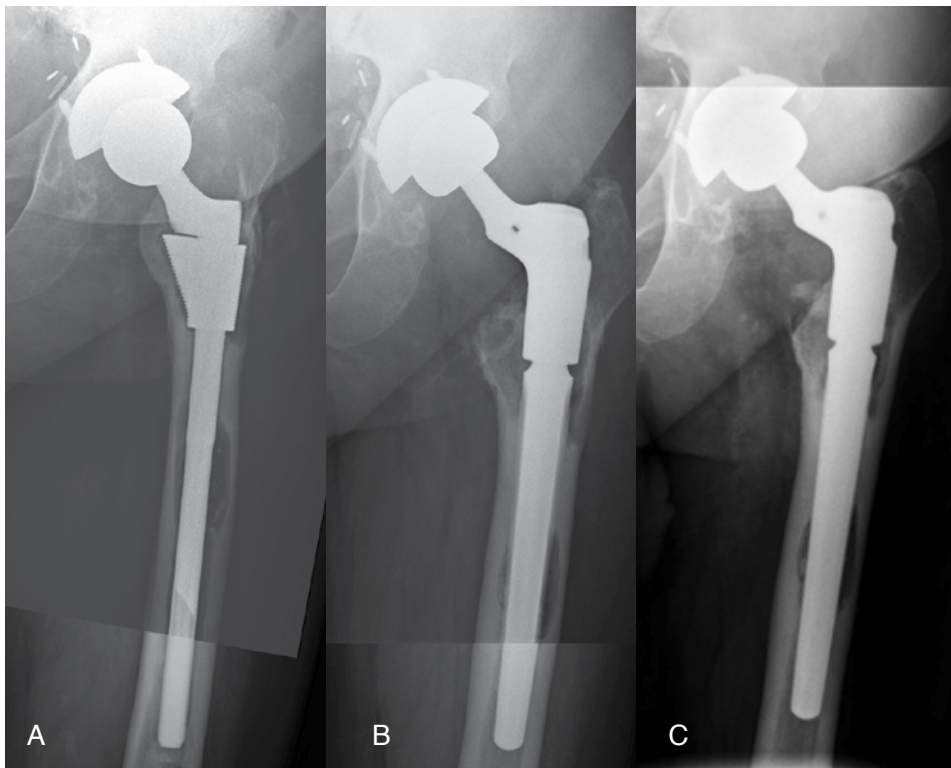
## Discussion

Early to midterm results of modular tapered stems used for femoral revision are now being published [5,6,11-18]. One study documented success in achieving implant stability and osteointegration, as well as restoring leg length and offset across all Paprosky classifications [15]. Multiple reports from one institution have demonstrated the success of modular tapered stems for cases of proximal femoral bone loss. The authors demonstrated high mid-term survival rates of 90-94%, maintenance or improvement of bone stock and low subsidence rates [4,13]. Higher outcome scores, better bone restoration and less intraoperative fractures were also found with modular tapered stems compared with fully porous coated cobalt-chromium stems [11,12]. In addition the modular tapered stems were typically used for cases of worse femoral bone loss. Two other papers document high midterm success with these stems in Mallory Type IIIC and Paprosky Type III and IV femurs [16,17].

Encouraging early results in treatment of periprosthetic femur fractures with modular tapered stems are also being reported. These stems were used in Vancouver B2 and B3 femur fractures. High rates of fracture union, maintenance of bone stock and implant osteointegration have been shown in these studies [19,20].

Modular tapered stems are valuable tools in femoral revision cases. The versatility of the design allows for independent attainment of implant fixation and hip stability, which can be challenging with mono-





*Figure 2. A 65-year-old male patient with BMI of 38.4 kg/m<sup>2</sup> presented to our practice 3 years after undergoing left revision cementless THA. He complains of pain and difficult ambulation. He describes the pain as moderate, in the buttock, and occurring intermittently. A) Preoperative radiograph reveals a cementless S-ROM revision femoral component with osteolysis and radiolucencies in all zones. B) Immediate postoperative radiographs reveal treatment with revision of the femoral component and exchange of the polyethylene liner. A cone standard offset body with 22.5mm diameter and 60mm length was used proximally, and mated with a 17x150mm splined tapered straight distal stem. A bone substitute putty was used to fill cavity defects in the femoral canal. C) At 2 years postoperative the patient is doing well with no pain and Harris hip score of 89. Radiograph reveals satisfactory component fixation and position, with progressive healing of osteolytic defects.*

block stems (Figure 2). The tapered geometry of the stem allows for its use even in severe cases of femoral bone loss which preclude the use of fully porous coated stems. Recent advances in design of the modular taper have led to a decrease in cases of stem fracture. While postoperative Harris hip scores are relatively low in the current series, they were significantly improved over postoperative levels, and likely have not reached maximum benefit given the early follow-up. Excellent radiographic results and early survival are encouraging for the use of this modular hip system in a variety of complex reconstruction scenarios.

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# Current Concepts in Trochleoplasty for Major Trochlear Dysplasia

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Although technically demanding, trochleoplasty can be useful as a primary procedure for primary trochlea dysplasia or as a salvage procedure in cases of failure after previous patellar alignment surgery.

## Introduction

The importance of a dysplastic trochlea as a component of patellar instability (especially recurrent dislocation or habitual dislocation) has been recognized for many years. It is usually combined with other static or dynamic abnormalities, such as genu recurvatum, patella alta, patellar tilt, increased Q angle, and bone torsional abnormalities.

Major trochlear dysplasia is characterized by the combination of flat and/or prominent trochlea with a convex shape that is proud of the anterior femoral cortex, rather than a concave geometry, which offer inadequate tracking during flexion and lead to patella subluxation, respectively [1,2].

Many surgical techniques have been proposed for the treatment of patellar instability. Trochleoplasty has been described as corrective treatment for bony abnormalities for many years, with the goal of restoring normal anatomy. Correcting the trochlear depth abnormality plays a major role to stabilizing the patella because it facilitates proper entrance of the patella into the groove of the trochlea. In our experience, restoration of the trochlea groove by trochleoplasty prevents future patellar dislocation and is effective in reducing anterior knee pain.

Elevation of the lateral trochlear facet was first described by Albee [3] in 1915, followed by deepening trochleoplasty, [2,4-12] which tries to create a new sulcus by removing subchondral bone. Recently,

Goutallier [13] proposed an easier concept, termed recession trochleoplasty, in which the bump is solely corrected with the trochlea remaining flat. This has now been adopted as our preferred technique [14].

Trochleoplasty is considered to be a demanding technique and may be avoided by many surgeons due to a lack of familiarity. However, it can be a useful addition to the surgical armamentarium of the patellofemoral surgeon and has precise indications.

Trochleoplasty can be proposed as a primary procedure for primary trochlea dysplasia or as a salvage procedure [13] in case of failure after previous patellar alignment surgery, principally anterior tibial tubercle transfer (ATTT).

In most cases, trochleoplasty is performed in association with other procedures (bony procedures such as ATTT transfer, or soft tissue procedure such as medial patello femoral ligament [MPFL] reconstruction). This combined procedures follows the concept of à la carte surgery described by Henri and David Dejour [1,7], which attempts to address all abnormalities during one surgical intervention.

## Principles

The first trochleoplasty involved the elevation of the lateral trochlea facet, as described by Albee [3]

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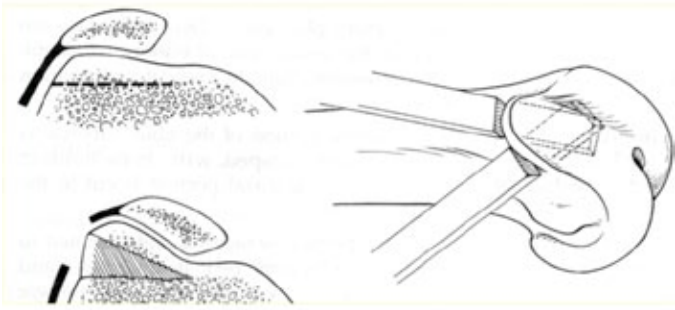


Figure 1. Elevation of the lateral facet, according to the Albee technique.

(Figure 1), addressing a flat trochlea by increasing the trochlear prominence. This method is now generally considered to be erroneous as it increases the patellar constraints, leading to secondary osteoarthritis. As a result, lateral trochlear elevation has fallen out of favor.

The second method is the deepening trochleoplasty. In 1966, surgery to correct the abnormality by deepening the sulcus was introduced by Masse [4]. He suggested the removal of subchondral bone and to impact the articular cartilage with a punch to recreate a central sulcus. This technique was later modified by Henri Dejour [2], who performed an osteotomy of both femoral condyles to create a V-shaped trochlear groove.

Von Knoch et al [5] described another technique known as “the Bereiter technique,” in which an osteochondral flap was raised from the trochlea and a bony sulcus was fashioned using burrs. The flaps were then depressed, making a smooth groove, and fixed by vicryl tape. This technique has been later described under arthroscopic control by Blønd and Schottle [6].

Deepening trochleoplasty, by any of these methods, is logical because it reduces the flatness and the prominence and attempts to restore a normal anatomy (Figure 2). There are several key points to be

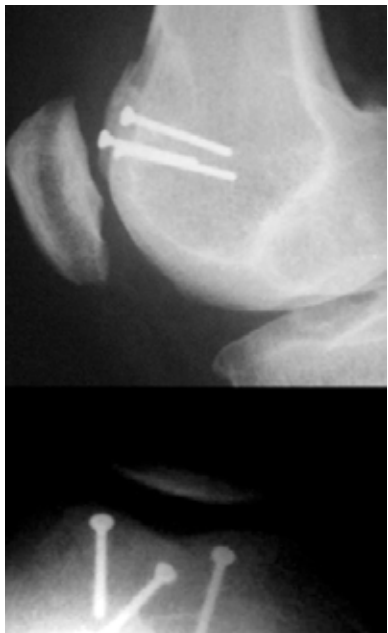


Figure 2. Deepening trochleoplasty. The trochlear groove has been restored but note the incongruity between the flat patella and the deepened trochlea.

considered when performing deepening surgery:

- Where should the trochlea sulcus be located when the trochlea is flat?
- What about the congruency between a flat dysplastic patella on a deepened trochlea? (Figure 2)
- What is the morbidity of this demanding technique, particularly bone healing and the risk of subchondral bone or cartilaginous necrosis?

The third type of trochleoplasty has been described by Goutallier et al [13], who performed a recession-

type trochleoplasty. In this procedure, the prominent dome-shaped anterior surface of the distal femur was recessed to the level of the anterior femoral cortex without deepening the groove itself. The aim was not to fashion a groove, but to reduce the prominent bump without modifying the patellofemoral congruence. This procedure is technically less demanding than a deepening trochleoplasty (Figure 3).



Figure 3. Recession trochleoplasty. There is a reduction of the prominence but the flat trochlea remains (crossing sign).

Recession trochleoplasty diminishes the trochlear bump, which improves patellar tracking, reduces lateral subluxation, and decreases patellofemoral constraint by increasing the angle between the quadriceps muscle force and the patellar tendon force. This has now become our preferred technique and we have reported the outcome of 24 cases of recession trochleoplasty performed between 2004 and 2009 [14] (mean age: 25; 12 primary procedures and 8 salvage procedures). Recession trochleoplasty was always performed with an additional procedure: 16 ATT transfers, 8 MPFL reconstructions.

## Preoperative Imaging

Preoperative imaging forms the key to determine when trochleoplasty is indicated. We have established a standard protocol of plain radiographs for visualisation of the patello-femoral joint. These con-



sist of AP view, lateral view at 20° of flexion, lateral view in full extension with quadriceps contraction, and skyline views at 30° in neutral rotation of the leg [15] and in external rotation (in order to demonstrate an eventual lateral subluxation). Additional bone imaging is provided by computed tomography (CT) [16].

The projection of the lateral radiograph is critical. By ensuring that the posterior aspects of the medial and lateral femoral condyles are superimposed, the bony anatomy of the trochlea can be compared. A number of key measurements and lines have been described based on this true lateral projection [1]:

- The Crossing Sign described by Walch characterizes the trochlea flatness.
- The trochlear bump or prominence is measured by the distance between a line tangential to the anterior femoral cortex, and a line parallel to this through the trochlear groove. A bump > 5 mm characterizes a major dysplasia (Figure 4)
- Patellar height may also be determined to consider an ATTT distalization procedure. We prefer to use the Caton Deschamps [17] index > 1.2

The lateral view in complete extension with quadriceps contraction allows assessment of the patellar tilt. (Figure 5) The “thick patella sign” characterizes a tilted patella, which appears thickened front to back.

CT scanning confirms the trochlear flatness and the trochlear prominence on sagittal sections, which can also be measured (Figure 6) according to Dejour’s classification [7]. It is important to consider that the dysplastic trochlea is lateralized compared to the center of the femoral epiphysis. This lateralization must be taken into account during trochleoplasty procedure.

The CT scan also measures the distance between tibial tubercle and the trochlear groove (TTTG). This is the traditional image-based determination of an increased Q angle [16]. Finally, CT scan permits assessment of the patellar tilt in extension: A tilt of more than 20° may be considered as an indication for additional soft tissue reconstruction.

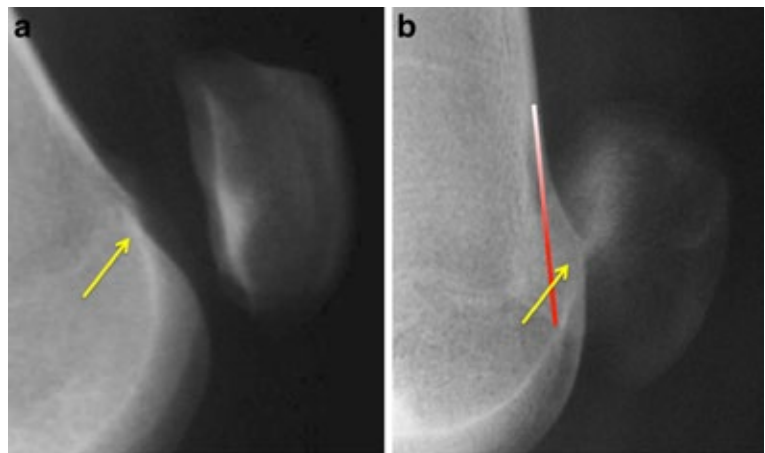


Figure 4. Different types of trochlear dysplasia a: crossing sign without prominence b: crossing sign and marked prominence demonstrating a major dysplasia.

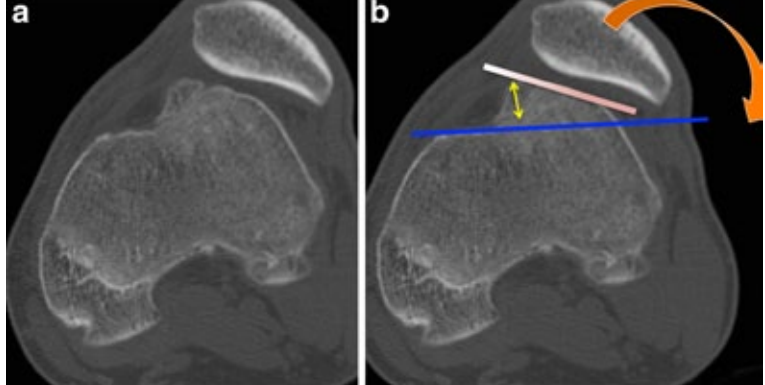
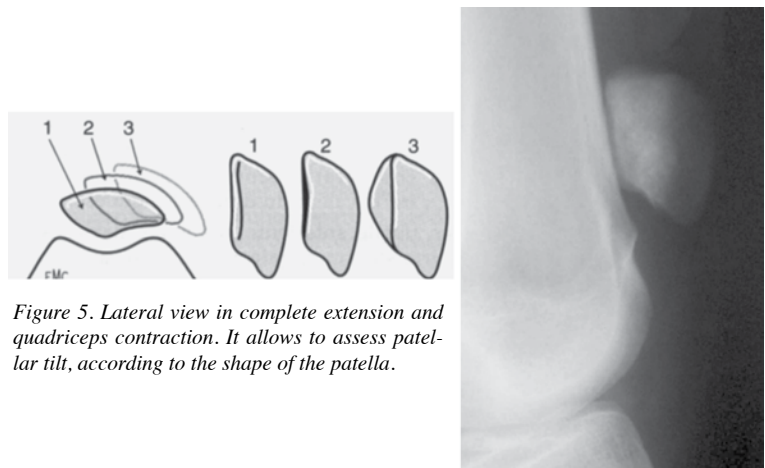


Figure 6. CT scan. It directly evaluates the trochlear prominence. The orientation of the trochlear plane and the trochlear lateralization explain patellar tilt and subluxation.

## Operative Technique

The procedure is performed with the patient supine. A tourniquet minimizes bleeding from the exposed areas of cancellous bone. Arthroscopy may be performed to confirm the absence of cartilage defect prior to trochleoplasty surgery. Two techniques – deepening trochleoplasty and recession trochleoplasty – are described below.



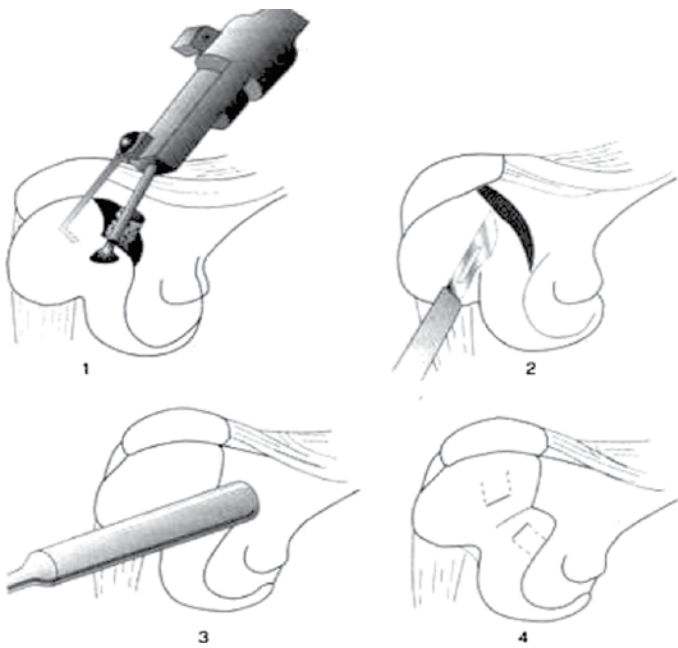


Figure 7. The steps of deepening trochleoplasty.

## Deepening Trochleoplasty

Dejour [18] proposed the following technique for deepening trochleoplasty (Figure 7):

- Arthrotomy is performed through a mid-vastus medial approach.
- The patella is translated laterally without eversion.
- Peritrochlear tissue is excised to visualize the anterior femoral cortex and define the amount of bone to be removed.
- The new trochlear sulcus is then drawn, starting from the top of the intercondylar notch and directing proximally with 3° to 6° of valgus. Lateral and medial facets are also demarcated.
- To access the undersurface of the trochlea, a thin strip of cortical bone is removed from the osteochondral edge, and then cancellous bone is removed from the undersurface of the trochlea.
- A drill with a depth guide of 5 mm is used to ensure uniform thickness of the osteochondral flap, which maintains an adequate amount of bone beneath the trochlear articular cartilage. The produced shell must be thin enough to be modeled without being sustaining a fracture.
- More bone is removed from the central portion at the location of the new sulcus. The groove, and sometimes the medial and lateral margins,

must be osteotomized.

- The osteochondral flap is then replaced and molded by gentle tapping with a punch.
- The new trochlea is fixed with two small staples (1 mm in diameter), one in each side of the groove. One arm is fixed in the upper part of the trochlear cartilage; the other one in the anterior femoral cortex. The staple is sunk deep to the superior surface of the cartilage.
- Patellar tracking is tested by flexing and extending the knee.

## Recession Trochleoplasty

We prefer to perform a lateral approach, as the dysplastic trochlea lies on the lateral aspect of the femoral epiphysis. Our technique aims to treat the underlying anatomic abnormality without compromising the articular surface.

- The incision is made just lateral to the patella, extending from the superior pole to the level of the patella to beyond the tibial tubercle, onto the anterior ridge of the tibia. This permits a tibial tubercle transfer to be performed during the same procedure if required.
- Once the lateral retinaculum is exposed, a lateral arthrotomy is performed using a size 10 blade.
- The synovium is excised and tethering scar tissues proximally and distally are released. The size of the wedge to be excised and the angle to be corrected are guided by pre-operative imaging and measured intra-operatively (Figure 8).
- The osteotomies are initially drawn on the bone with a dermatographic pen according to the pre-operative planning (Figure 9). Using a reciprocal saw, the antero-posterior cut is performed first, 5 mm above the trochlea.
- Then the posterior cut is made, parallel to the frontal plane of the femur, from the lateral side, and directed medially. It is more precise to start the cut with a rigid osteotome and to complete it with the saw. The distal extent of the osteotomy should be approximately 5 mm away from the sulcus terminalis to give an optimal distal osteochondral hinge and to allow closing the wedge easily.
- An anterior oblique osteotomy completes the bone cuts linking the first two cuts.
- The proximal-based bone wedge is then re-

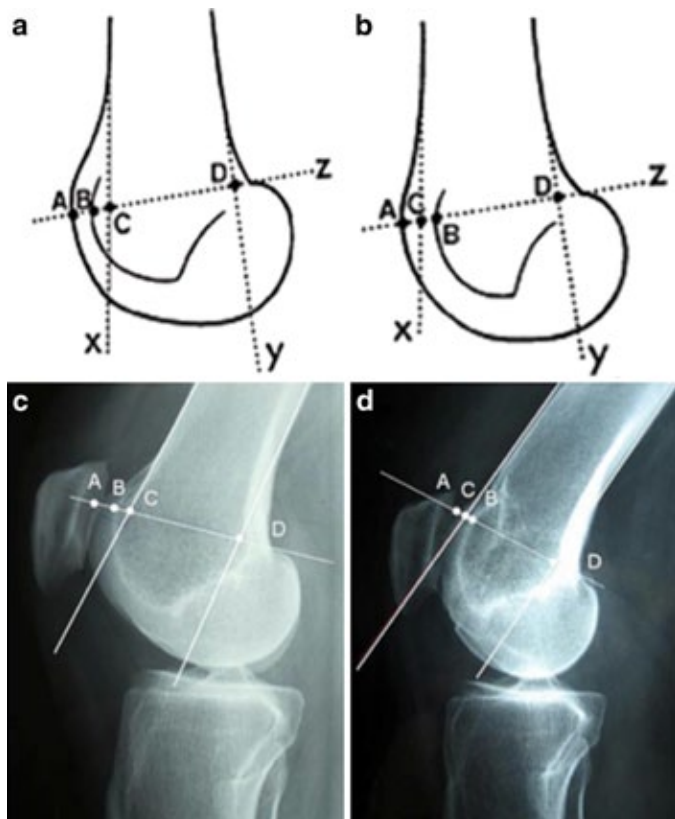


Figure 8. Pre- and postoperative bump height measurement technique. A and B: Drawings showing the Dejour and Walch method for calculating the bump height. Point “D” is the junction between the posterior cortex and articular cartilage. Bump height is measured between points “B” and “C”. C: Pre operative lateral radiograph: the boss height is positive. D: Post operative lateral radiograph: the boss height is now negative.

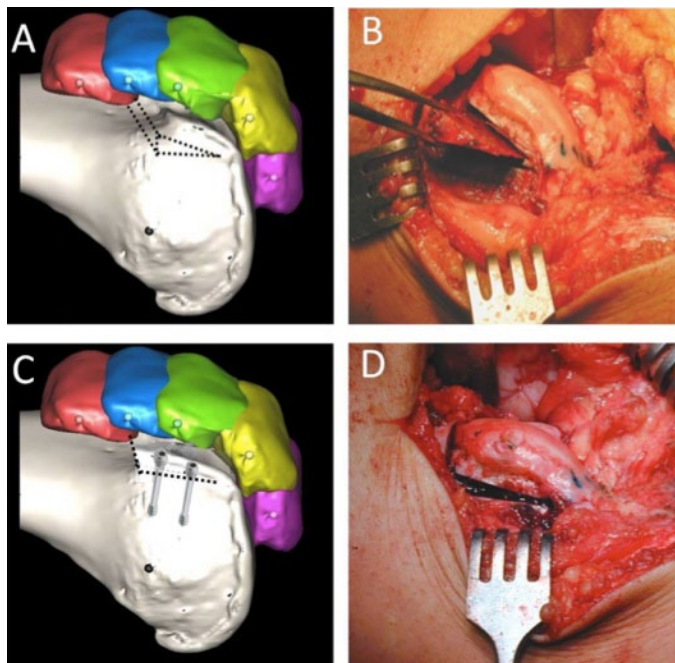


Figure 9. The recession wedge trochleoplasty surgical technique. A and B: The base of the wedge which is removed should be the same in millimeter that the value of the trochlear bump in order to allow the trochlea to settle into a deeper position, without modifying the trochlear groove. C and D: The correction is obtained after removal of the proximally based wedge by progressively applying a pressure on the trochlea. Fixation is carried out with two 3.5-mm cancellous screws, positioned just laterally to the cartilage surface.



10a



10b

Figures 10a-b. Postoperative X rays after Recession wedge trochleoplasty. A: lateral view showing the reduction of the trochlear prominence. B 30° patello femoral view showing the extracartilaginous position of the screws.

moved and correction is achieved by progressively applying sustained gentle digital pressure on the trochlea. The amount of bone removed is just enough to allow the trochlea to settle into a deeper position, without modifying the trochlear groove.

- The correction is secured using 3.5-mm cancellous screws, positioned just laterally to the cartilage surface (Figure 10). We now use two lateral screws only, and so far have had no problems.
- Postoperatively the knee is placed in an extension brace for the initial 3 weeks. Full weight-bearing is allowed. Knee flexion is restricted to 0° to 60° for the first 3 postoperative weeks, and then slowly increased to reach 90° on the

sixth week. Return to sports is allowed at 6 months.

## Results

### *Complications/Safety*

The risks of the deepening trochleoplasty include breaking of the osteochondral flap; distal detachment; and creating a flap that's too thin, decreasing its blood supply. There are still concerns about the viability of the articular cartilage after trochleoplasty. Recession wedge trochleoplasty has a decreased risk of chondral damage and necrosis. Because the dysplastic segment of trochlea is lifted as a single osteochondral block and there is no need to fashion a new groove by cutting the osteochondral flap, it is possible to preserve a greater amount of subchondral bone. This makes recession arthroplasty a more attractive option for older patients with less pliable cartilage, with decreased risk of possible serious and irreversible articular and subchondral injury. In our series, we reported no cases of chondrolysis, subchondral necrosis, or non-union of the osteochondral block.

It is worthy of note that in cases of recession trochleoplasty, the wedge and the trochlear recess are flat and complementary, whereas in the deepening trochleoplasty, the osteochondral flap might not tally perfectly with the V-shaped recipient bone bed. Any small areas of separation between the two surfaces could slow down the osteointegration process. Similarly, the use of screw to stabilize the osteotomy rather than sutures may increase compressions between the two surfaces. Surprisingly, chondrolysis has never been reported with the deepening trochleoplasty.

Schottle [19] studied the cartilage viability after the Bereiter trochleoplasty. He found that tissue in the trochlear groove remained viable, with retention of distinctive hyaline architecture and composition and only a few minor changes in the calcified layers.

Postoperative stiffness is of considerable concern [8,11-13] and varies from 2% to 46%. In our series, one patient with combined MPFL required arthroscopic arthrolysis for knee stiffness 1 year after the index operation. Another patient required an arthroscopic supratrochlear exostosectomy for a persistent ridge responsible for pain. He was also satisfied and had no complaint at the last follow-up visit and reported no further episodes of instability.

### *Clinical Outcomes*

To date, published outcomes of both deepening and recession trochleoplasty are similar, with improved subjective outcome scores reported in the short term [4,8-14,18]. Comparisons between series are difficult because the surgical procedures and follow-up periods are variable, the number of patients is often small, and patients have been operated on for mixed indications of pain rather than dislocation [12,13]. Moreover, it is not possible to assess the participation of trochleoplasty in the patellofemoral stability because it is rarely performed alone, and other abnormalities are corrected as part of the surgical procedure. As a result, there is a lack of high-level studies reported in the literature.

In Goutallier's case series in which trochleoplasty was performed as a salvage procedure, 67% of patients indicated that they were either satisfied or very satisfied with the outcome of surgery. Other series showed 100% satisfaction rates.

In our series, the operation failed to stabilize the patellofemoral joint in only two cases. The average objective knee score at last follow up was 80 (+/-17) for the Kujala score [20], 70 (+/-18) for the KOOS and 67 (+/-17) for the IKDC. Patients who had a previous surgery, as well as those with patellofemoral chondral lesions noted during the surgery or degenerative changes on the preoperative radiographs, were noted to have a lower Kujala score at last follow up.

Interestingly, all patients operated on for pain-free instability (n = 7) reported having slight pain. This was located at the site of screws to reattach the tibial tubercle and so was not directly related to the trochleoplasty itself. All patients with preoperative pain except one (n = 11) reported significant pain improvement at last follow-up.

### *Radiologic Outcome*

Both deepening and recession trochleoplasty reduce the trochlea bump. In our series, the trochlear groove height changed from an average of 4.8 mm preoperatively to an average of -0.8 mm postoperatively (Figures 7, 8, 10). Patellar tilt changed from an average of 14° (6° to 26°) preoperatively to an average of 6° (range -1° to 24°). It is interesting to note that there was no significant difference in the correction of the patellar tilt angle when comparing the groups did or did not have adjunction of a MPFL reconstruction. Thus, our series suggests that MPFL reconstruction is not necessary when a recession wedge trochleoplasty is performed. The reduc-



tion of the boss height allows the avoidance of lateral misdirection and facilitates the sliding of the patellar into the trochlea recess.

Deepening and recessing trochleoplasty are effective in reducing anterior knee pain, but they do not halt the progression of patellofemoral arthritis – although the follow-up of the above studies is too short to draw any definitive conclusions. In our series [14], at the time of the latest follow-up, six knees had osteoarthritic changes in the patellofemoral compartment, according to the classification by Iwano et al [21]. These are similar to the results obtained with deepening trochleoplasty [5]. Trochleoplasty cannot be proposed as a prevention of late osteoarthritis.

## Conclusion

Trochleoplasty is indicated as a primary procedure for major trochlear dysplasia with a prominence > 5 mm. Stabilization is obtained in most of the cases with the risk of residual mild anterior knee pain. Trochleoplasty can be also proposed as a salvage procedure when a previous surgery fails. In these cases, one can expect stabilization of the knee and improvement of anterior knee pain.

Reported results are encouraging in terms the prevention of redislocation and satisfaction index. The rate of complications is low. Long-term outcomes have not been reported, and there are no consistent data on the capacity to prevent secondary arthritis.

Technically speaking, the deepening trochleoplasty is a difficult procedure. Recession wedge trochleoplasty is easier to perform. It is never an isolated procedure but always in conjunction with other realignment procedures according to the a la carte surgery concept.

## Source

Beaufils P, Thauinat M, Pujol N, Scheffler S, Rossi R, Carmont M. Trochleoplasty in Major Trochlear Dysplasia: Current Concepts. *Sports Medicine, Arthroscopy, Rehabilitation, Therapy & Technology* 2012, 4:7 doi:10.1186/1758-2555-4-7. <http://www.smartjournal.com/content/4/1/7>. © 2012 Beaufils et al; licensee BioMed Central Ltd. This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/2.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

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# Initial Misdiagnosis of a Traumatic Ceramic Femoral Head Fracture

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and Daniel Kendoff<sup>†</sup>

A destructive ceramic head fracture was diagnosed 1 year after a serious motorcycle accident in a patient who had undergone primary THA 7 years earlier.

## Introduction

In the 1970s, Boutin implemented ceramic in modern total hip arthroplasty (THA). Although initial fracture rates of 13.4 % for ceramic heads were described before the 1990s, the inferior rate of wear and friction when compared with metallic heads and the optimized tribology were promising in THA [1-3]. Gradual improvements in processing of the material led to a significant reduction of the fracture rate to below 0.1 % [3]. Thus, alumina ceramic heads have currently become the standard material in THA with ceramic bearing surfaces.

Nevertheless, multiple case reports have been published describing ceramic head fractures [4-11]. The causes of fractures are diverse and vary from traumatic events [5,9,12,13] to impingement between the neck and the liner rim [7]. Spontaneous fractures without any history of trauma have also been described [4,6,8,10,11]. However, only two reports describing delayed fractures of ceramic heads were found [12,13].

In this report, we present a 24-year old patient who underwent primary THA at our institution and was a victim of high-energy trauma 7 years later. Initial radiographs were misinterpreted in a non-designated total joint clinic at the time of primary admission (after the accident). A destructive ceramic head fracture was diagnosed more than 1 year after initial



Figure 1. Anteroposterior pelvic radiograph (24-year-old male) after primary THA for secondary osteoarthritis due to Perthes disease (right hip: cementless CFP stem and TOP acetabular cup; left hip: hybrid THA with cemented ENDO Mark III stem + cementless TOP acetabular cup; Waldemar Link GmbH, Hamburg, Germany).

trauma at our institution, with major destruction of the ceramic head and the remaining THA.

This was followed by an extensive revision. Based on this experience, the general question of adequate radiographic diagnosis after trauma to a THA, especially one with partial or full ceramic bearing surfaces, will be further discussed in this report.

## Case Report

A 24-year old patient with secondary osteoarthritis of the hips due to Legg-Calve-Perthes disease underwent primary hybrid THA of the left hip seven years before trauma, followed by primary cement-

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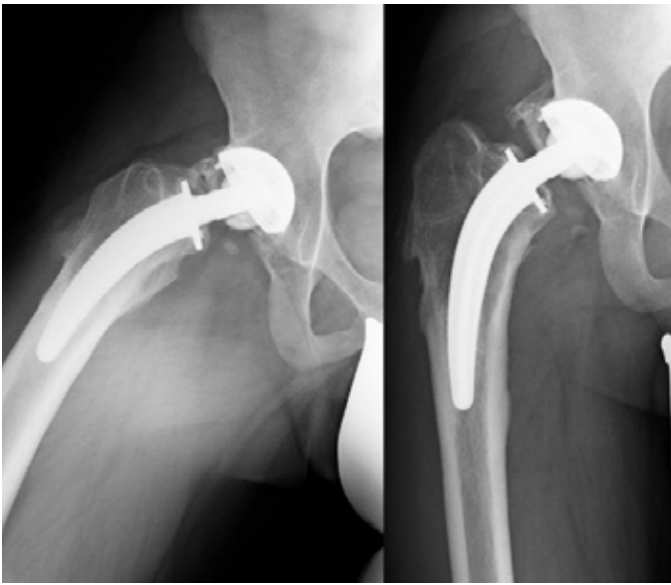


Figure 2. Conventional pelvic radiographs directly after trauma, revealing ceramic head fracture.

less THA of the right hip 1 year later at our institution (Figure 1).

Six years after the right THA, he was involved in a motorcycle accident, in which he suffered direct trauma to this hip, as well as a complex ankle fracture that was treated in a smaller regional hospital on admission.

Although initial anteroposterior radiographs of the pelvis and right hip axial views were performed, no signs of fractures, aseptic loosening, or implant damage were diagnosed by the attending trauma surgeons (Figure 2). Two weeks after surgical treatment of the ankle fracture, the patient noticed a sudden “cracking” sound in his right hip, as well as shortening of the right lower limb. Interestingly, the patient had no relevant pain.

Despite this sign, he had no further medical observation or secondary radiographic evaluation over the next month. In the following months, he was increasingly troubled by back pain and an unpleasant cracking “phenomenon” with movement of his right hip; no severe hip pain or associated direct thigh pain was mentioned at any time.

Further conventional radiographs, in two planes, more than a year after the initial radiographs, revealed a completely destroyed, multi-fragmented ceramic head (Figure 3).

A thorough clinical examination revealed a shortening of 2 cm of the right lower limb, yet the patient was able to walk without relevant pain.



Figure 3. Anteroposterior pelvic radiograph 8 months after the initial radiographs, showing a fractured ceramic head.

## Management

Intraoperatively, extensive damage of the ceramic head and correlating taper junction of the femoral neck was found (Figures 4-6). Concomitantly, there was severe debris-related metallosis throughout the entire joint (Figure 7).

The intervention consisted of conversion of the short cementless CFP stem to a cementless revision stem and an acetabular cup revision to a ceramic-ceramic bearing surface (Alloclassic stem and Allofit-IT acetabulum with Delta Ceramic Inlay, Zimmer, Warsaw, Indiana, USA, and CeramTec, Plochingen, Germany).

Meticulous debridement of all affected soft tissues and extensive lavage were also performed.

The postoperative course was uneventful, with radiographs revealing a correct position and articulation of the cementless implant (Figure 8).

A 12-month postoperative inquiry was performed and the Oxford Hip Score obtained, with both indicating satisfactory joint function [14]. The patient had no pain and was able to perform his daily activities.

## Discussion

Although a relatively rare complication in modern THA, the described ceramic head fracture was misinterpreted in initial radiographs, which showed a discreet fracture of the ceramic head. Two assumptions



Figure 4. Intra-operative image showing countless debris and the damaged taper junction of the femoral neck (in situ).



Figure 5. Intra-operative image showing the fragmentation of the ceramic head.

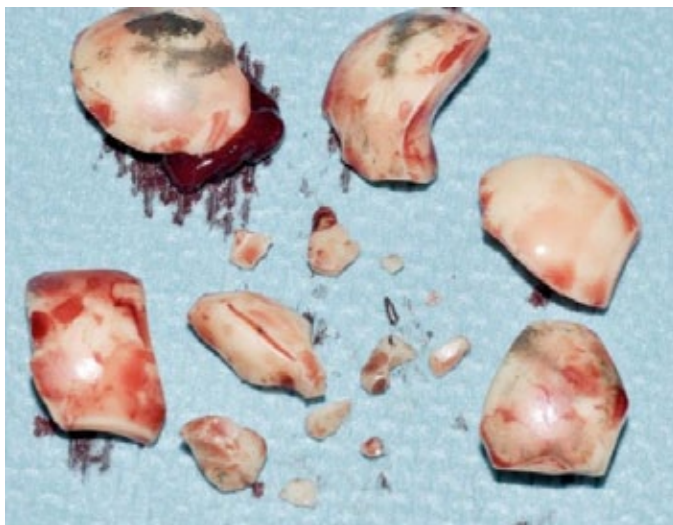


Figure 6. Image showing the explanted components: a fragmented ceramic head, a damaged stem, and acetabular cup and liner.



Figure 7. Intra-operative image showing debris with ceramic fragments.



Figure 8. Postoperative anteroposterior pelvic radiograph.

can be made which led to this misdiagnosis. Firstly, the complex ankle fracture was probably more painful than the ceramic head fracture and this misled the surgeons. Secondly, although the initial radiographs revealed a ceramic head fracture, the staff at the initial center of admission did not have the training necessary to reach the correct diagnosis.

The “cracking sound” incident 2 weeks after trauma, as described by the patient, was probably due to the complete fracture of the ceramic head. Ultimately, a multi-fragmented ceramic head fracture was diagnosed 1 year later. This raises the question of the need of a possible guideline or recommendation for patients suffering acute trauma of the lower limb with a total hip arthroplasty, especially those with ceramic bearing surfaces.

This case remarkably demonstrates the variability and intensity of symptoms: When one considers the implants’ damage, the patient was able to walk without any pain originating from the hip. His only complaint was mild back pain over the subsequent months. This clearly represents a challenge for the assisting physician to obtain a correct diagnosis. The



post-traumatic patient who previously underwent THA should therefore be carefully followed. We suggest a close follow-up including repeat conventional radiographs several weeks after trauma. Furthermore, in some cases, a CT-scan could provide the correct diagnosis [15].

Ultimately, if a definitive diagnosis cannot be assured at the initial assessment center (eg, a low-volume or non-dedicated joint replacement center), consideration should be given to transferring the patient to a dedicated joint replacement center.

We present our case report to increase awareness among physicians and training staff who treat trauma patients with a previous total joint replacement and to expedite the diagnosis of possible post-traumatic implant fractures/failures in the future.

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#### *Source*

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# Successful Closed Reduction of a Dislocated Constrained Total Hip Arthroplasty

Motoki Sonohata<sup>†</sup>, Warit Waewsawangwong<sup>‡</sup>, Stuart B. Goodman<sup>§</sup>

This case report and literature review examines whether closed reduction is a viable option to manage hip dislocation when the patient has a constrained liner.

## Introduction

Dislocation after total hip arthroplasty (THA) ranges from less than 1% to 6% of primary cases [1] and from 15% to 30% of revision cases [2]. Unfortunately, the success rate of non-operative treatment of dislocation after THA can be unreliable, and a third of such patients have recurrences [1].

Surgical procedures used to treat instability and dislocation include:

- Tightening the abductor musculature
- Removing sources of impingement
- Repositioning malaligned components
- Using acetabular liners with elevated rims

Such treatments fail in 30% to 50% of patients, however [3].

The use of constrained liners, which relies on a locking mechanism to capture the femoral head, has been developed to help manage this problem [4]. Despite such efforts, patients continue to be at high risk for instability, and 3% to 18% experience recurrent dislocation even after constrained components have been implanted [5,6]. Generally, open surgical reduction is thought to be the only available treatment for such cases. However, this compromises the integrity of the joint and exposes the patient to the additional risk of surgery [7]. Several authors have reported closed reduction for dislocation of a constrained liner [7-13].

Constrained acetabular liners are currently avail-

able in various designs, with differences in the locking mechanisms. To our knowledge, ours is the first reported case of a successful closed reduction of a dislocated constrained THA using a Trilogy Acetabular System Constrained liner (Zimmer, Inc, Warsaw, Indiana, USA).

The study protocol adhered to the ethics guidelines of the 1975 Declaration of Helsinki, and the study was approved by the Institutional Review Board of Stanford University.

## Case Report and Management

A 79-year-old female underwent primary THA for nonunion of a right subtrochanteric fracture of the femur with degenerative arthritis of the right hip joint using an uncemented Trilogy acetabular system and fully porous-coated stem (Zimmer, Warsaw, Indiana, USA). Five years later, at age 84, the hip was revised to a Trilogy constrained liner with a 10° oblique face and 32-mm head (Zimmer, Inc, Warsaw, Indiana, USA) (Figure 1) for instability and recurrent dislocation (Figure 2).

However, 5 years after the revision surgery, at age 88, she bent over, hyperflexed the hip, and complained of right hip pain. A radiograph in the emer-

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Figure 1. Trilogy constrained liner with a 10-degree oblique face (Zimmer, Inc, Warsaw, Indiana, USA).

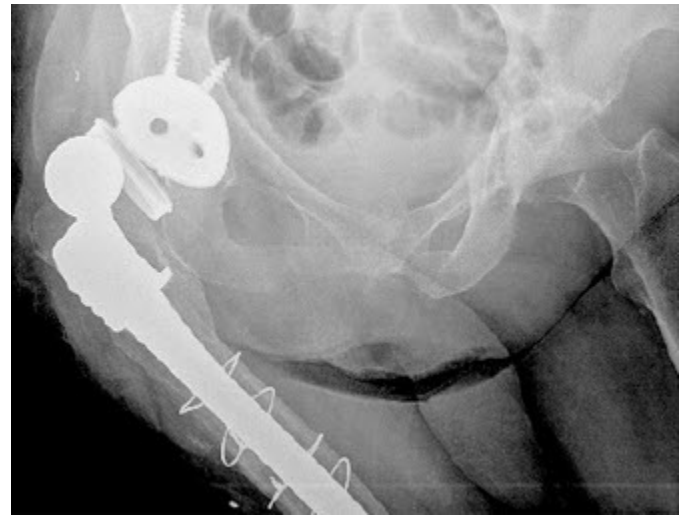


Figure 3. Anteroposterior radiograph of dislocation of the right hip.



Figure 2. Radiographs before dislocation. (A) Anteroposterior view, (B) Lateral view.

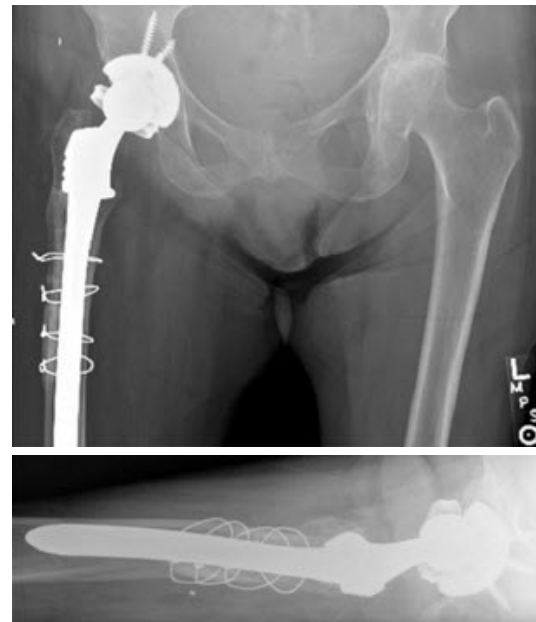


Figure 4. Radiographs after closed reduction. (A) Anteroposterior view, (B) Lateral view.

gency department in our hospital demonstrated dislocation of the constrained THA. The head appeared to have dislocated from the liner, and the locking ring disengaged but was not broken (Figure 3).

A closed reduction was performed in the emergency department with sedation. The head was relocated and the locking ring was repositioned to where it was previously located (Figure 4). The patient's hip was placed in an abduction brace with full weight bearing. Further radiographs demonstrated no further change. The patient could ambulate with minimal aid.

The patient died 10 months later of unrelated causes.

## Discussion

Dislocation after THA using a constrained polyethylene liner presents a substantial treatment challenge. Closed reduction provides a conservative treatment option that avoids the risk of open surgical reduction. This point is especially relevant considering the surgical complications that exist in older patients with recurrent instability and a complex revision history [9].

Several authors have described successful closed reduction of a dislocated constrained liner [7-13]. Generally, it is thought that plastic deformation must occur in the polyethylene during the initial disloca-

tion and during the closed reduction process. The torque required for subsequent dislocations for a second and third time decreased by 24% and 8% in the Poly-Dial constrained liner (DePuy, Warsaw, Indiana, USA), respectively [9].

However, not all patients undergoing closed reduction of constrained liners require revision surgery or experience recurrent dislocations. Harman et al [9] reported that six hips remained stable 7 to 72 months after the last reduction. They noted that two of six hips underwent repeated successful closed reduction within 6 months of their initial dislocation and reduction and remained stable for at least 3 years.

In contrast, McPherson et al [7] reported that three hips with constrained liners required further operation after closed reduction. Two patients underwent revision surgery after 1 and 3 months their initial dislocation and reduction, and one patient was converted to a Girdlestone resection arthroplasty after 6 months.

Our current case underwent closed reduction once, and did not require any further surgery.

Closed reduction techniques for dislocated constrained liner were reported in seven papers [7-13]. Adequate anesthesia and usage of fluoroscopy were common described in these papers. The procedure of closed reduction for dislocated liner was formed in two steps.

- First, traction was applied and the femoral head was placed in a “perched” position on the acetabular cup. The hip was positioned in 10-40 degrees abduction during traction [7,9-12]. Additional hip flexion was described in two papers, in full extension in one [9]; however, Flint et al adopted in-line traction for the limb [13].
- Second, the femoral head should be passed through the constrained liner with axial compression after confirmation that the femoral head was perched just lateral to the rim. In this phase, hip flexion was increased to 30-90 degrees from first step [7,9,11].

Direct medial pressure was also placed to the greater trochanter [7,9,10,13]. Gaines et al [12] reported an anomalous closed reduction. They initially failed at closed reduction; however, the patient's femoral head subsequently reduced naturally the next day.

The most commonly used femoral heads for constrained liners are 28 mm and 32 mm in diameter. Harman et al [9] reported no successful closed reductions of a 32-mm femoral head in their eight patients.

They described that the force to relocate the 28-mm heads into constrained liners in vitro was 1380 N (310 lb), whereas 32-mm heads required greater force. Six 28-mm and one 32-mm head were relocated into constrained liners [9-13]; however, the details of implants and clinical results at follow-up concerning of the case of 32-mm head were unclear [10].

In the current case, the patient's femoral head was 32-mm head with Trilogy constrained liner (Zimmer, Warsaw, Indiana, USA).

Four constrained liners are currently in common use:

- Omnifit liner (Stryker, Mahwah, New Jersey, USA)
- S-ROM liner/Poly-Dial (DePuy, Warsaw, Indiana, USA)
- RingLoc constrained acetabular liner (Biomet, Warsaw, Indiana, USA)
- Trilogy constrained liner (Zimmer, Warsaw, Indiana, USA)

Given substantial differences among constrained components from different implant manufactures, several reported closed reduction techniques may not be applicable to specific constrained acetabular components.

Our case is the first report of successful closed reduction of a dislocated constrained total hip arthroplasty using the Trilogy constrained liner and a 32-mm head. In the aging population with complex medical issues, closed reduction may obviate the need for a more invasive open procedure, or at least restore patient function until revision THA can be electivity planned. An attempt at closed reduction may be indicated unless the acetabular component has failed at the liner-shell interface, shell-bone interface, or the locking ring has fractured.

The limitation of this case report was that the follow-up period was only 10 months. Therefore, it is unclear whether recurrences of dislocation might happen with longer-term follow up.

#### Source

Sonohata M, Waewsawangwong W, Goodman, SB. Successful Closed Reduction of a Dislocated Constrained Total Hip Arthroplasty: A Case Report and Literature Review. *The Open Orthopaedics Journal*, 2012, 6, 211-214. doi: 10.2174/1874325001206010211. <http://bentham-science.com/open/openaccess.php?toorthj/articles/V006/211TOORTHJ.htm>

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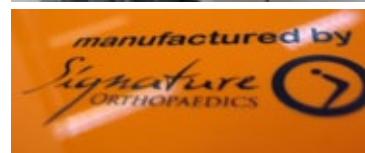
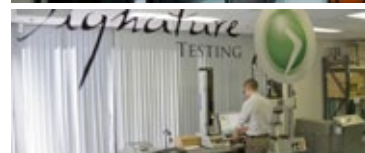
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# A Rare Dissociation at the Neck–Stem Interface

A. Kouzelis<sup>†</sup>, C.S. Georgiou<sup>†</sup>, and P. Megas<sup>†</sup>

The authors report a case of dissociation at the neck–stem interface without hip dislocation that occurred during walking, and discuss strategies to avoid and treat this complication of THA.

## Introduction

Modular femoral components have the advantages of:

- Reducing the need to stock numerous stem and head sizes
- Allowing the final choice of neck length and head size to be made after stem implantation

With modular femoral components, neck orientation can also be changed after implantation, which is a well-known cause of early dislocation. The incidence of postoperative dislocation of modular total hip arthroplasty (THA) varies from 0.5% to 4% [1].

Dissociation at the neck–stem interface is rare. To the best of our knowledge, only three case reports have been published [2–4], but they pertained to dissociation at the neck–head interface.

We report a case of dissociation at the neck–stem interface without hip dislocation that occurred during walking, and we discuss the causes of dissociation as well as strategies to avoid and treat this complication.

## Case Presentation and Management

A 72-year-old man had undergone a right THA in 1996. Revision THA was performed in our institution in 2005 due to aseptic loosening of both components.

After intraoperative extraction of the acetabular shell, we determined that a jumbo acetabular com-

ponent (Procotyle, Wright) was needed to manage the serious acetabular bone loss that was discovered. Allograft augmentation of the acetabulum was also used to repair the defect.

The acetabular shell was 60 × 68 mm in outer diameter; additional fixation was achieved with three cancellous screws. The polyethylene liner was group 2, 15°, 28 mm in inner diameter.

For the femoral component, which was fully porous-coated and therefore distally fixed, we used a modular stem (Profemur-R, Wright). The open-book technique was used to extract it, and a transverse osteotomy just under the tip was also made, which we use in such cases to avoid distal extension of the osteotomy (open-book technique) and to preserve good bone stock for the distally fixed stem.

Postoperative radiographs revealed adequate positioning of the THA components (Figure 1). The usual protocol for THA postoperative treatment was used, and patient mobilization began on the second postoperative day. The patient was discharged on the eighth postoperative day, fully mobilized (partial weight-bearing) and without residual problems.

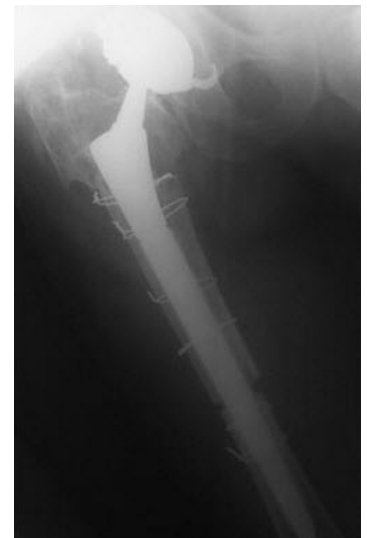


Figure 1. Radiograph after the first operation reveals good relationship of the total hip prosthesis with acetabular and femoral bones.

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The patient gave informed consent to publish this case.

## Postoperative Course

The usual clinical and radiographic follow-up during the first and third months was normal. The patient was satisfied with the result of the operation and was mobilized with two canes, according to the instructions of the surgeon.

One month later (4 months postoperative), the patient arrived at our emergency department unable to walk and with pain in the revised hip. At clinical presentation, he reported an incident of sudden pain and then falling during normal walking and with no extreme hip movement or rotation. Radiographs revealed dissociation of the modular stem at the femoral neck–stem interface without dislocation of the head (Figure 2).

Immediate revision surgery was performed to re-affix the neck to the main body of the prosthesis. During the operation, stability testing of the acetabular shell revealed adequate fixation of the prosthesis. A new modular interchangeable neck system was implanted; however, as this type of stem also has a modular proximal component, we decided to change it to prevent further complication at the proximal component–stem junction.

All intraoperative stability and orientation tests were normal. Postoperative radiographs were normal (Figure 3).



Figure 2. Radiograph shows dissociation of the femoral neck–stem interface.



Figure 3. Radiograph after the second operation reveals reimpacted new femoral neck–stem component. Notice the absence of ectopic bone from the lesser trochanter area.

## Discussion

The use of modular components greatly increases flexibility during THA, but also introduces the risk of failures at the interfaces and possible intraoperative errors in matching. Dislocation is a potential problem after THA [1,5,6], and dissociation of modular components after dislocation is unique to modular systems.

Dissociation can occur during closed reduction of dislocation at two different interface levels: the fixed acetabular shell–polyethylene liner interface [2,7–13], and the femoral head–neck interface [2–4]. In our case, dissociation occurred at the femoral neck–stem interface, with no previous traumatic incidence. To the best of our knowledge, no such case concerning this type of prostheses had previously been reported.

The manner in which this incident occurred reveals inadequate modular component fixation or a repetitive force that provoked micromovement of the modular interface that finally led to component dissociation. Potential causes of dissociation during normal walking are as follows:

Inadequate orientation of femoral neck resulting in stress forces at the stem–neck interface. In our case, orientation of the femoral and acetabular components cannot be reliably evaluated due to the absence of a computed tomography (CT) scan of the indexed hip.

Excessive telescopic movements, which finally led to dissociation by creating negative pressure in the acetabular area. Computer-assisted measurement of distal stem migration showed a subsidence of 3.6 mm at 3 months, which is considered excessive for this short postoperative period, though it is expected for this type of revision stem and transfemoral approach [14] (Figure 4).

Such an early stem subsidence and subsequent leg shortening can result in loss of intraoperative soft tissue tension and, eventually, in hip-joint instability.

Impingement of the femoral neck at the acetabular shell or at osteophytes in the area, causing mechanical stresses at the finally dissociated interface. As mentioned above, component-to-component impingement cannot be confirmed in our case. However, we consider bony impingement to be more important for this patient. Arc length between the tip of the greater trochanter and the ilium (GT arc) has been shown to correlate with free hip flexion and abduction before impingement [15]. In this case, mini-

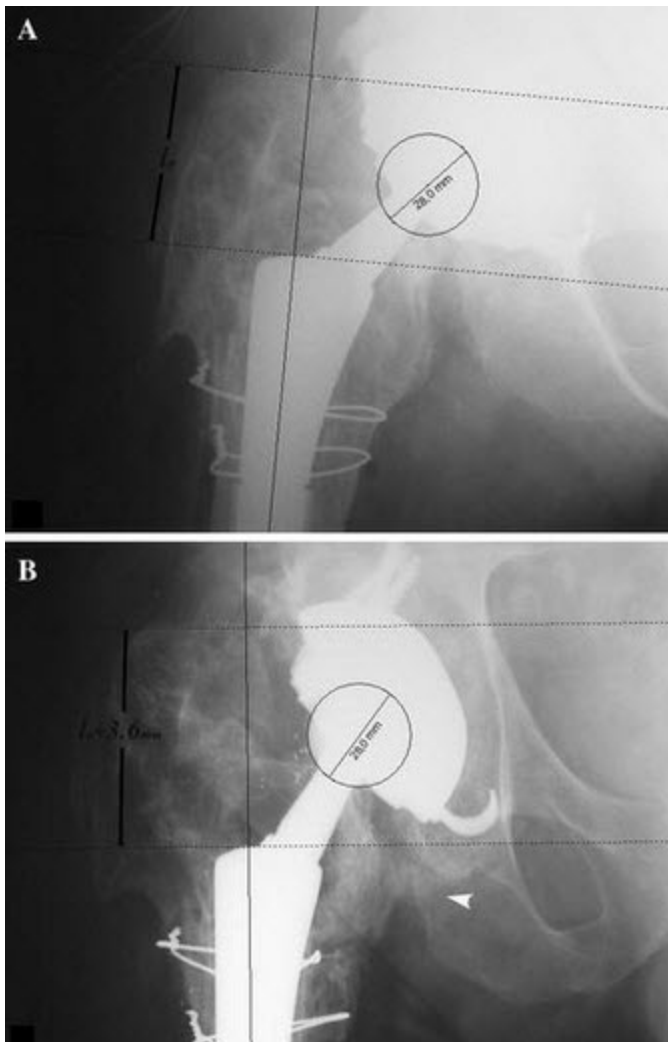


Figure 4. Stem subsidence was measured by processing immediate postoperative (a) and 3-month (b) follow-up anteroposterior radiographs via Roman v1.7 software (Roman free to share software version V1.70; Robert Jones and Agnes Hunt Orthopaedic Hospital, Oswestry, UK; <http://www.Keele.ac.uk/depts./rjah/>), as a change in the vertical distance from the proximal tip of the greater trochanter to the shoulder of the stem. Ectopic bone formation at the lesser trochanter area (white arrowhead) is noted 3 months postoperatively (b).

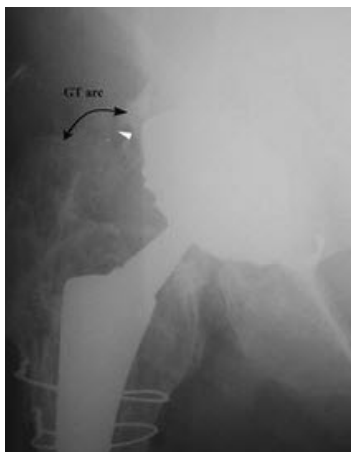


Figure 5. Minimal greater trochanter (GT) arc length and high position of the tip of the GT in relation to the head center predicts early impingement of the GT to the ilium. A bone spur (osteophyte) at the tip of the GT (white arrowhead) may further limit impingement-free range of motion.

mal arc length and the high position of the tip of the greater trochanter in relation to the head center predicts early bony impingement (greater trochanter to ilium) (Figure 5).

In a computer model, it has been shown that once bony impingement becomes the restricting factor, further changes in implant design and orientation may not improve range of motion (ROM) [15]. Furthermore, in a cadaver study of hip dislocation, osseous impingement was likely to occur between the greater trochanter and the iliac wing before component impingement [16]. Similarly, bony impingement preceded component impingement in about 44% of all conditions tested in a three-dimensional computer model with varying orientations of the femoral and acetabular components [17].

Ectopic bone formation causing abnormal movement of the joint. Heterotopic ossification can cause hip-joint instability when the periarticular bone mass limits femoral excursion or contributes to impingement [18]. However, to our knowledge only in two cases was hip dislocation directly attributed to heterotopic ossification [19].

Modular titanium alloy neck adapters, such as the one used in our case, can fail due to surface micromotions, according to recent retrieval examinations and biomechanical simulation [20]. Whether this movement leads, apart from fatigue fracture, to neck dissociation is unclear. Nevertheless, in large case series with similar neck adapters applied, no case of dissociation was reported [21].

In our case, a jumbo cup was used due to extensive bone loss to ensure stable primary fixation. Three cancellous screws were also placed for the same reason. Regarding the femur, the main goal was successful diaphyseal fixation of the stem; therefore, a long, fully porous-coated, trapezoid-shaped stem was used.

For the modular neck, a straight 0° long neck was selected, allowing fine positioning of the stem in relation to the cup. Although unnecessary [22], three medium hammer blows were applied to fix the neck–stem coupling.

Intraoperatively, during the second revision, a large amount of ectopic bone was found in the lesser trochanter area, which is a possible cause of stem impingement and, in particular, the neck–stem interface, which may lead to dissociation due to repetitive stresses and micromovement in the area. The ectopic bone was removed, and intraoperative mobilization revealed free movement of the hip joint in all pos-

sible directions.

Modular components give the surgeon an intraoperative advantage but also increase the potential for component mismatch and mechanical failure. Dissociation is a rare but possible cause of failure.

To prevent this complication, the femoral neck component should be impacted firmly onto the tapered stem base during the operation. Finally, free movement of the joint is essential to prevent abnormal stresses at the interfaces of the modular components.

### Source

Kouzelis A, Georgiou CS, Megas P. Dissociation of modular total hip arthroplasty at the neck–stem interface without dislocation. *Journal of Orthopaedics and Traumatology* Official Journal of the Italian Society of Orthopaedics and Traumatology © The Author(s) 2011. <http://dx.doi.org/10.1007/s10195-011-0172-9>. <http://link.springer.com/article/10.1007/s10195-011-0172-9/fulltext.html>

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# Tibial Stress Fracture After Computer-Navigated Total Knee Arthroplasty

*F. Massai<sup>†</sup>, F. Conteduca<sup>†</sup>, A. Vadalà<sup>†</sup>, R. Iorio<sup>†</sup>, L. Basiglini<sup>†</sup>, and A. Ferretti<sup>†</sup>*

In this case report, the patient experienced a stress fracture at one of the pinhole sites used for placement of the computer navigation system's tibial trackers.

## Introduction

The use of computer navigation systems in total knee arthroplasty (TKA) has become increasingly popular in recent years. Many authors have already documented satisfactory short- to mid-term results after using various types of software [1-3].

Bathis et al [4], as well as Decking et al [5] and Rosenberger et al [6], showed how the use of navigation systems can improve the accuracy of the femoral and tibial component placement when compared with the "traditional" techniques. Because a correct alignment of the components is one of the most important factors determining favorable long-term results of a TKA, this could lead to a higher longevity of the prosthesis.

Despite these positive aspects, some authors have reported no advantages, as well as a longer operative time with the use of computer-assisted systems [7,8]. Moreover, recently three cases of stress femoral or tibial fractures have been reported as a complication of navigated TKA [9,10].

We present a case of a stress fracture of the tibial diaphysis that occurred after a TKA performed with the use of a computer navigation system. The stress fracture occurred at one of the pinhole sites used for the placement of the tibial trackers.

We have been using computer navigation systems since 2005 as a standard procedure for TKA. This complication occurred after a series of 155 (0.64%)

uncomplicated procedures (ie, well after the learning curve was complete).

## Case Presentation

A 79-year-old woman (height 155 cm, weight 68 kg) with painful bilateral knee osteoarthritis was surgically treated at our orthopaedic institute with a total knee replacement on the left side. No previous operations had been done on her left knee.

The pain had begun 7 years earlier; however, in the 10 months preceding surgery, the patient experienced a sudden worsening of the pain with subsequent restrictions of important daily activities. Conservative treatment was performed and judged as useless by the patient. Consequently, she was given a surgical option.

Before the operation, the range of motion (ROM) of the patient's left knee was 5–100°, with pain at the last degrees of flexion and extension. Patellofemoral crepitus, widespread tenderness, and mild effusion were also detected at the physical examination. Walking and ability to climb stairs were severely compromised and possible only with the use of crutches.

A bilateral knee valgus deformity was registered with a left knee valgus of 12°. Preoperative radiographs showed a severe osteoarthrosis with significant reduction of the external compartment joint space.

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## Management

With the patient in a supine position and with the use of a tourniquet, an antero-medial approach of the left knee was performed under spinal anaesthesia. Prophylactic antibiotics were administered in a single dose before surgery. A low-contact-stress rotating-platform prosthesis (Complete LCS, DePuy International Ltd, Leeds, UK) was used; neither the femoral nor the tibial component was cemented.

The operation was performed by the same expert surgeon who had already performed more than 100 computer-assisted procedures before this operation with the same software and hardware. A computed tomography (CT)-

free navigation system (Ci™ navigation system, DePuy I-Orthopaedics, Munich, Germany) was used. To perform the electronic measurements, one bicortical navigation tracker (5 × 200 mm) was set at the distal part of the femur and two bicortical navigation trackers (4 × 130 mm) were set on the tibial diaphysis (Figure 1).



Figure 1. Trackers set on the tibial diaphysis.

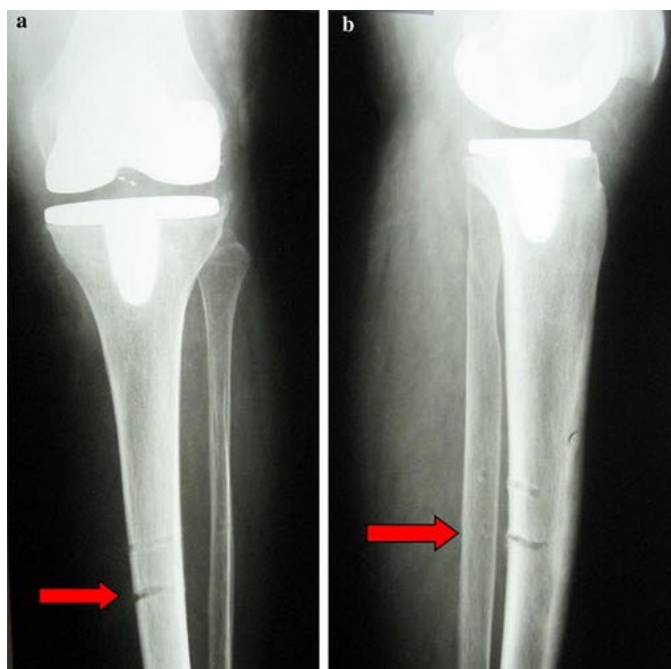
### Postoperative Course

The outcome was excellent in the first 3 weeks after the operation: The skin incision completely healed and the patient was able to walk with crutches without pain or restrictions.

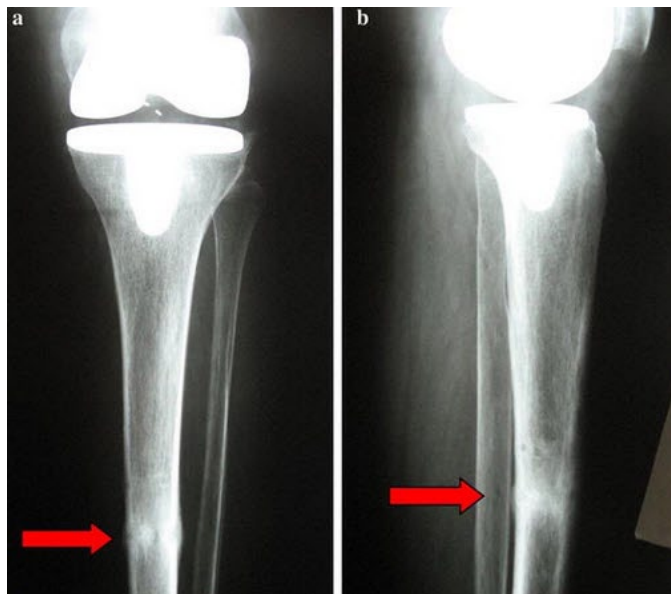
However, at the beginning of the fourth postoperative week, an acute pain appeared in the operated leg with local tibial pain and swelling. The patient immediately had an X-ray check-up which revealed a stress fracture of the diaphysis of the tibia, at the level of the more distal tibial tracker (Figures 2a-b).

As a result, the patient wore a brace and was instructed to avoid weight-bearing for the following 4 weeks. After 4 weeks, she was allowed to gradually weight-bear with use of a leg cast for another 4 weeks. Subsequent X-rays at the 14th week showed good healing of the fracture (Figures 3a-b).

The patient was followed up at 7 months. Clinically, a satisfactory outcome was reported by the patient, with a good recovery of her daily activities; crutches were no longer needed to walk. Physical ex-



Figures 2a-b. a - Antero-posterior (AP) X-ray: stress fracture at the level of the distal tibial tracker. b - Latero-lateral (LL) X-ray: stress fracture at the level of the distal tibial tracker.



Figures 3a-b. a - AP X-ray: good healing of the tibial stress fracture. b - LL X-ray: good healing of the tibial stress fracture.

amination showed a lack of tenderness at the level of the stress fracture; final ROM of the affected knee was 0–120°. The Knee Society score [11] was 94.

Radiologically, the stress fracture was completely healed and the left lower limb showed a good alignment (Figures 4a-b).

The patient provided her consent to the publication of the case report.



Figures 4a-b. a - 7-month follow-up AP X-ray: complete healing of the fracture. b - 7-month follow-up LL X-ray: complete healing of the fracture.

## Discussion

Stress fractures after TKA are not common and they are usually related to preoperative osteoporosis, femorotibial malalignment, or other concomitant diseases.

Our report presents a case of a patient who underwent a knee replacement without any postoperative complications or factors that would lead the surgeon to expect any particular complication. The onset of a stress fracture on the tibial diaphysis 3 weeks after the operation represented an interesting event. X-rays clearly showed how the tibial fracture occurred right where the tibial pins for the navigation trackers were set; more specifically, where the distal tibial pin was set.

The type of navigator used required the insertion of two pins on the tibia, and the diameter of such pins is rather large (5 mm for the femoral tracker and 4 mm for each of the tibial trackers). In accordance with Ossendorf et al [10], we believe that the insertion of such pins (especially if in a pair) can significantly decrease the breaking stress of the bone locally and in the surrounding area.

Brooks et al [12] and Burstein et al [13] have already shown the positive correlation among screw holes in bone and the residual weakness of the bone to afford bending loads and torsional stresses. As a consequence, the occurrence of a fracture at the pin insertion site should always be considered.

This is especially true in cases in which bicortical pins are used because their penetration in the tubu-

lar bone occurs in a “transcortical” way, or in cases in which they are inserted in the cortical bone as a result of several attempts to obtain a perfect stability of the pin.

That is exactly what happened in our case, as the distal tibial pin was inserted twice due to a lack of stability of the tracker obtained after the first attempt. Indeed, a critical review of the postoperative X-ray shows a slightly larger diameter of the distal tibial hole.

The use of a bicortical pin, especially if inserted more than once, could increase weakness of the local bone; however, this hypothesis contrasts with the results provided by Kuo et al [14], which showed how bone stress concentration after single-cortex defect was similar to double-cortex defect. However, the use of bicortical pins provides a better stability of the navigation trackers, which is a priority in performing a correct computer-assisted knee surgery.

For all our patients treated with the computer-navigated system, weight-bearing is allowed progressively and always with the use of crutches. Patients are instructed that the amount of weight-bearing depended on their pain. Because we did not see stress fractures in our other similarly treated patients, we do not believe that an excessive weight-bear contributed to the occurrence of the stress fracture by itself.

In summary, we recommend paying particular attention to inserting the pins in an orthogonal way, reaching the distal cortical bone without completely penetrating it. This should provide adequate stability of the trackers, reducing the risk of loss of strength of local tibial bone.

Moreover, patients with concomitant diseases (such as rheumatoid arthritis or osteoporosis) or who are receiving concomitant drug treatment (such as corticosteroids) should be kept under particular control and, if necessary, undergo a slower postoperative rehabilitation protocol.

## Source

Massai F, Conteduca F, Vadalà A, Iorio R, Basigliani L, Ferretti A. Tibial stress fracture after computer-navigated total knee arthroplasty. *Journal of Orthopaedics and Traumatology Official Journal of the Italian Society of Orthopaedics and Traumatology* © The Author(s) 201010.1007/s10195-010-0096-9. <http://link.springer.com/article/10.1007/s10195-010-0096-9/fulltext.html>

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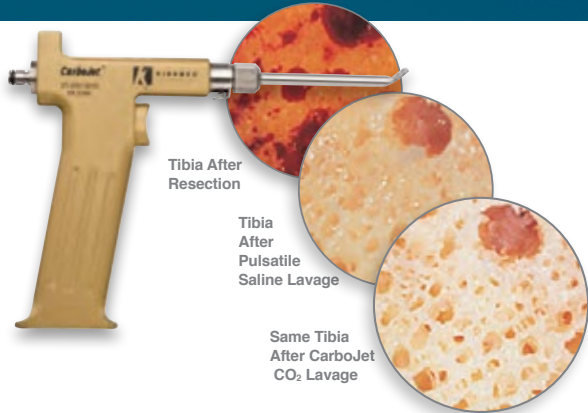
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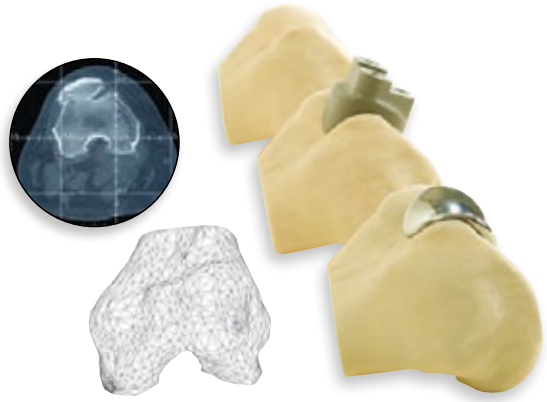


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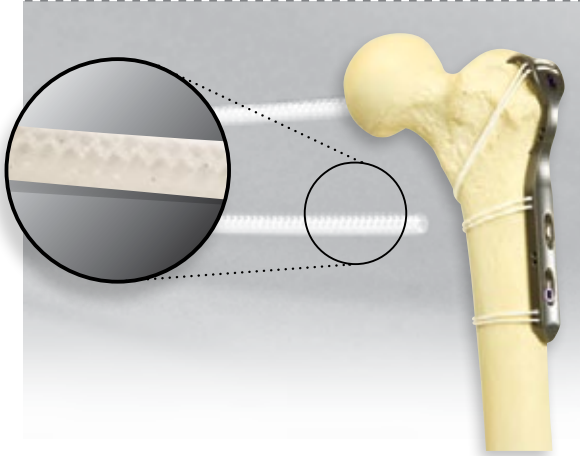
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# Stage II Osteointegration Implant (OI) Skin Coupling Procedure

(Continuation from Case Report September 2013)

(First Reported Case in U.S.)

**Ronald Hillock, MD\*¥,**

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*Acknowledgement: Design concept by Concept Design & Development, LLC (CDD,LLC);  
Development and Manufacturing by Signature Orthopaedics, LTD; Centennial Hills Hospital  
Medical Center, Las Vegas, NV; and Institutional Review Board (IRB) by Joint Implant  
Surgery & Research Foundation.*

## Background

Patient's over health was unchanged following stage I procedure, 8/17/2013, 123 days post surgery.

The patient had been followed closely since the time of the stage I procedure. The patient was 65 years of age at the time of the Stage II procedure, 12/18/2013. Her wounds at the residual limb had completely healed without any problems by 14 days after the Stage I surgery. Her pain medication requirement was completely resolved by day 21 after the Stage I surgery. She had worn a stump shrinking compressive staking for the majority of the time leading up to the Stage II procedure; the patient reported that the pressure on the residual limb was comforting. The scar was tender over the lateral aspect of the residual limb with a positive Tinel's Sign [1] and no palpable mass or swelling.

A planning full length standing radiograph of both limbs on a long image cassette was obtained (see figure 1). All imaging studies showed the femoral implant positioned as it had been on the day of the Stage I procedure with progressive evidence of boney ingrowth as demonstrated by the plain film images.



Figure 1. Preoperative radiograph used to plan stage II surgery. Demonstrates more than 10 cm space from the end of the femoral stem to the joint line of the contralateral knee.

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β Signature Orthopaedics, Sydney, AU

## Day of surgery

The patient was prepared for surgery following standard protocols. She was NPO for 8 hours prior to anesthesia. Preoperative laboratory testing showed no abnormalities.

Please review Dr. Andrew Zak's article on the anesthetic method employed in this patient's surgery.

Standard prophylactic intravenous antibiotic was given, Cefazolin [2] 1gm, was administered on entering the operating room.

## Positioning

The patient was positioned supine on a standard radiolucent operating table. The right lower limb was then prepped with ChloroPrep® [3] circumferentially from the inguinal fold to the terminal aspect of the stump. Impervious split drapes and paper split drapes were then applied.



Figure 2. Draping and positioning of patient.



Figure 3. Fluoroscopic imaging was used during the procedure.

Fluoroscopic imaging figure 2 & 3 was used throughout the procedures, total image time was 25 seconds, divided over 6 static images.

## Procedure

After standard surgical skin preparation and draping the terminal stump was palpated to confirm the position of the previously implanted stem. Fluoroscopic images were used to confirm the orientation of the female coupling mechanism of the stem.

The soft tissue about the distal stem was then infiltrated by the surgeon with a 18 gauge 6 cm needle. A cocktail of Duramorph [4] 10 mg, Ketorolac Tromethamine [5] 30 mg, and Ropivacaine [6] with epinephrine in a total volume of 60 ml was injected/infiltrated into the tissues about the stem to supplement the anesthesia field block.



Figure 4. A 18 gauge 6 cm needle was then used to administer a cocktail of Duramorph [7] 10 mg, Ketorolac Tromethamine [8] 30 mg, and Ropivacaine [9] with epinephrine in a total volume of 60 ml.

A sterile spear tipped 2 mm k-wire was then advanced through the skin into the distal aspect of the stem by hand, metal on metal contact was palpable through the wire. The wire was manipulated to engage the internal threads of the femoral stem, engagement was confirmed with fluoroscopic images as well.

A 18 mm cannulated circular cutting instrument was then advanced over the 2 mm wire until metallic contact was palpated.





Figure 5. A 18mm circular hand cutting trephine was used to expose implant.

The device was advanced with hand pressure along the axis of the wire through a steady twisting motion. The path from the skin to the stem was then cleared of remaining soft tissue with a #10 scalpel. Electrocautery was used to obtain homeostasis. Total blood loss during this procedure was less than 25 ml.

A depth gauge was then passed down the path and engaged into the female coupling. The thickness of soft tissue from the end of the stem to the skin surface was measured and found to be 2 cm.



Figure 6. A depth gauge was then passed down the path and engaged into the female coupling.

The 2 cm coupling device was then selected and advanced into the female coupling.

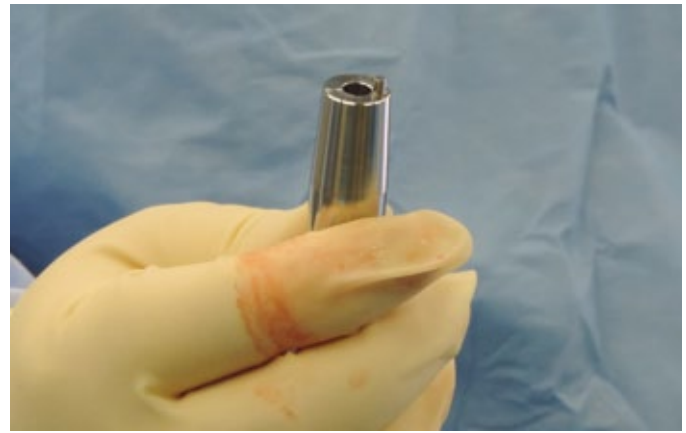


Figure 7. The 2 cm coupling device was then selected and advanced into the female coupling.

The tapered portion was gently manipulated to engage the stem female opening. The shear pin was oriented at the 6 o'clock position to align with the stem's matching receptacle. The device engaged with minimal effort. A locking screw was then advanced into through the coupling device into the threads of the femoral stem. The screw engaged without incident and was advanced until it was felt to be tight enough. Fluoroscopic imaging confirmed the implant position and alignment was consistent with visual inspection of the device.



Figure 8. Implant positioning was checked with Fluoroscopic imaging.

A silicon sleeve was then passed over the coupling device to create a barrier between the soft tissues and the implant to prevent the formation of a tight seal.



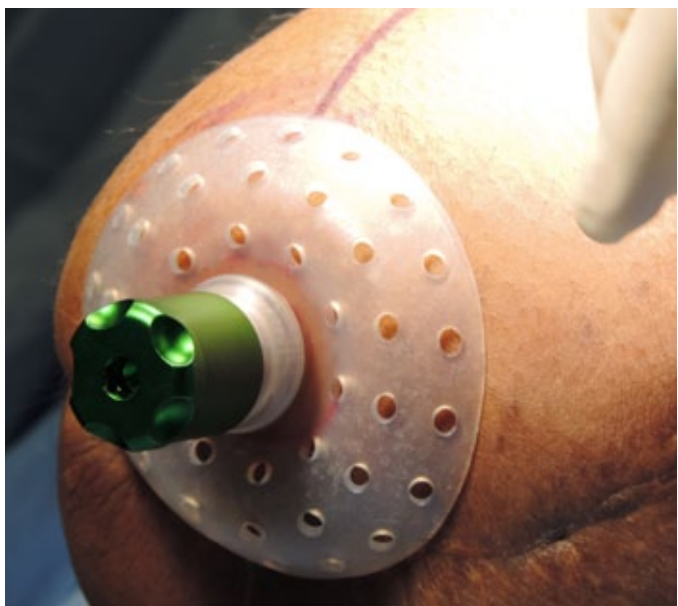


Figure 9. Silicon sleeve in place.

The intended goal was to create a stoma through which the coupling device passes from the skin to the stem. A series of end protectors were then attached to the coupling device to prevent damage to the implant during the rehabilitation therapy to follow.

## Dressing

A dressing was then built in multiple layers. The skin implant level was dressed with a piece of Silverlon® [10] dressing material cut to slide over the coupling device, measuring roughly 4 cm x 4 cm.



Figure 10. Silverlon dressing applied.



Figure 11. 4x4 dressing applied.

This was then reinforced with sterile 4 cm x 4 cm gauze sponges, 6 layers thick. A silicon basket was then placed over the stem to compress the sponges and firmly secure their position.



Figure 12. An ABD dressing in place.



The entire dressing mass was then over warped with a sterile 10 cm compressive ace wrap, applied in a figure of 8 amputation compression technique.

### Postoperative Care

The patient was then held on a post surgical care ward for 23 hours after surgery. She received 2 additional doses of cefazolin per standard surgical protocol for all orthopedic procedures. Her pain was controlled, a personal controlled anesthesia unit had been made available and was used for a total of 3 self administered doses of 0.2 mg hydromorphone2 over the 8 hours following surgery. Ketorolac3 injection was available as a back up medication for break through pain but was not needed. She stated that she had no pain at 20 hours post surgery, the next morning.

The dressing was changed at the bedside the next morning and there was minimal staining (see figure). The patient was counseled on wound care and dressing methods. She was advised that she could shower and allow soapy water to flow over the wound/prosthesis area but not to submerge the area under water for an additional 2 weeks. The patient was advised that the Silverlon® dressing could be recycled by cleaning in water, being applied in a moist yet not wet state. The Silverlon® dressing can be used and

recycled with simple water baths for up to 30 days per the manufacturer's recommendations.

Physical therapy ambulated the patient to confirm safety and stability with a walker. The patient was discharged to home for further out patient care. Physical Therapy was started 2 weeks after surgery, please refer to separate report for the rehabilitation protocol to follow.

A final report will be presented in approximately three months as follow up demonstrating the patient fitted with final leg prosthesis and her progress.

Both patient and development team remain very optimistic that this alternative treatment will provide an improved functional outcome as compared to traditional socket prosthesis.

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# Anesthesia and Pain Control for Osteointegration Implantation Into the Femur

## Stage II Osteointegration Implant (OI) Skin Coupling Procedure

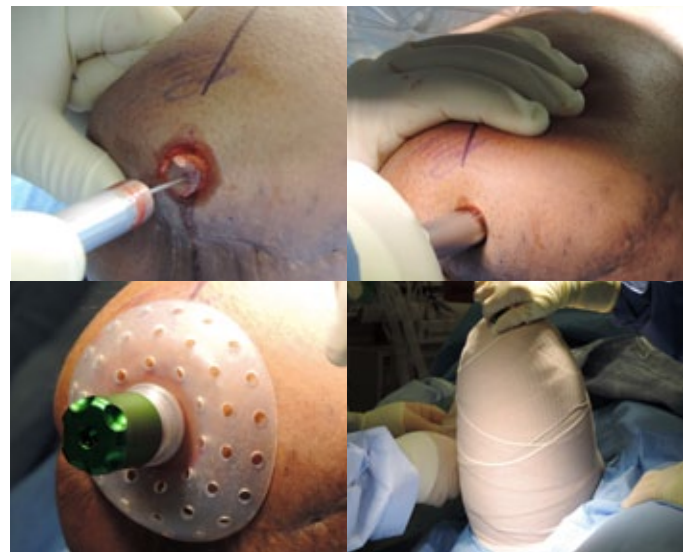
*Andrew Zak, MD<sup>†</sup>, Ronald Hillock, MD<sup>‡</sup>*

The success of our index case employing the use of the Osseointegration Implant (OI) is largely due to the coordinated efforts of the assembled team of medical professionals including nursing, surgeon and anesthesiologist. The anesthetic methods and techniques were a central component of each of this patient's surgeries. This is a report of the anesthetic methods employed in managing this patient's pain before, during and after the implantation with the novel Longitude™ OI device.

The index patient was well known to the team having undergone multiple prior surgical procedures at our institution. This report will detail the anesthesia provided at the time of the transfemoral amputation, followed by the Stage I implantation of the Longitude™ OI device and finally concluded at the time of the stage II docking through the skin procedure. In each case the patient was offered neuraxial subarachnoid block [1] and declined.

### Medical History

The patient was a 65 year old female at the time of the transfemoral amputation. The patient was in a well managed state of health, with routine long term out patient care by her Internist. She had been diagnosed with essential hypertension that was well controlled with oral furosemide 20 mg daily. She had a history of latex allergy with both cutaneous hypersensitivity and systemic anaphylactic reactions on contact with latex on multiple prior occasions. The patient had been diagnosed with Juxacortical Chondrosarcoma of the right distal femur prior to her planned elective transfemoral amputation. She had



undergone multiple prior surgeries to remove the tumor from the right lower extremity starting with the first attempt at the age of 16 years. The diagnosis of a malignant cartilage lesion was not confirmed until a few months prior to the planned right transfemoral amputation. For these reasons the patient was assigned an American Society of Anesthesiology Score [2] of 3, severe systemic disease.

The patient's prior anesthetic episode records were reviewed, the patient had tolerated all prior procedures and anesthetics without complication.

### Right Transfemoral Amputation

The patient was taken to the operating room (OR)

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and standard non-invasive monitors were applied, and pre-oxygenation by face mask was initiated. Pre-operative antibiotics were administered intravenously (iv) upon OR entry, about 15 minutes prior to skin incision [3]. In accordance with the Joint Commission's universal protocol for the prevention of wrong site, wrong surgery and wrong person guidelines the operative limb was confirmed by the anesthesiologist, the operative surgeon, the circulating nurse and the surgical technician by review of the written history and physical, the signed consent for surgery, patient interview/questions as well as the surgeon's initials at the surgical site [4].

Once the surgical site had been confirmed the patient was dosed with 250 mcg of Fentanyl [5], 10 mg metaclopramide [6] and 20 mg Famotidine [7]. After two minutes of pre-oxygenation, 100 mg lidocaine [7] was given iv, followed immediately by 200 mg propofol. 30 seconds later, a Laryngeal Mask Airway [8] (LMA) was inserted orally; the LMA had been pre-treated with 2% lidocaine [7] jelly. End tidal carbon dioxide tracing was confirmed and hand ventilation was initiated to assist ventilation and to maintain oxygen saturation [9]. Subsequently, as the patient began to ventilate spontaneously and oxygen saturation was greater than 97%, vaporized inhaled desflurane [10] was initiated for maintenance of general anesthesia. The surgery proceeded without complication. The surgeon injected sciatic nerve with 10 ml of 0.25% bupivacaine [15] with epinephrine prior to ligation and transection. As surgical dressings were applied and the desflurane discontinued and the patient aroused adequately to allow removal of the LMA. The patient was observed to ventilate spontaneously. Nausea prophylaxis was given in the form of ondansetron [11] 4.0 mg iv. The patient was recovered in the Post Anesthesia Care Unit, and was subsequently transferred to the orthopedic ward for in patient care.

#### *Stage I: Implantation of OI implant into the residual femur*

The second surgery occurred approximately two months later. This surgery involved implanting the OI device into the remaining femur. The anesthetic technique was identical to that which was employed during the amputation. The patient's peri-operative care was uneventful.

#### *Stage II: Coupling the OI implant through the skin*

The third surgery occurred approximately 123 days after the Stage I procedure, and involved the coupling or exteriorization of OI implant through the skin of the right transfemoral amputated limb. The patient agreed to undergo an anesthetic technique employing a femoral nerve block, along with moderate sedation.

The surgical site confirmation protocol [4] and prophylactic antibiotic [3] pre-medication steps were performed per standard protocol prior to any invasive steps. The nerve block was performed in the pre-operative holding area. 4 mg midazolam [12] was given iv as the skin was prepped and draped in a sterile fashion. Ultrasound guidance was used to locate the femoral vessels and nerve [13]. The skin was anesthetized with 2% lidocaine [14] and a 22 gage stimulator needle was visualized immediately lateral to the femoral artery. There was no electric nerve stimulator utilized during this nerve block. A total of 30 ml of 0.5% bupivacaine [15] with epinephrine was injected in 5 ml aliquots surrounding the femoral nerve. There were no parasthesias and aspiration before each 5ml injection was negative.

After induction of anesthesia the surgeon infiltrated the operative site with a cocktail of ketorolac [16] 30 mg, morphine [17] 10 mg and ropivacaine [18] 40mg with saline in a total volume of 60 ml via a 10 cm 18 gauge needle. Intra-operative sedation consisted of 100 mcg fentanyl [1] iv and a total of 200 mg propofol [19] given incrementally throughout the course of the anesthetic episode which lasted approximately 90 minutes. During the intra-operative care, the patient maintained spontaneous ventilations breathing oxygen via a standard face mask with an oxygen flow of 10 liters per minute. The patient required no airway support of any kind, recovered uneventfully and was transferred to an orthopedic in patient ward.

#### **Post Operative Care**

The patient was held on an orthopedic ward for 20 hours after the surgery. A Patient controlled anesthesia [20,21], (PCA) device loaded hydromorphone [22], set to deliver a demand dose of 0.2 mg at a 10 minute lock out, no loading dose, no continuous infusion, was provided for the first 16 hours after surgery. The patient used the PCA for a total of 3 demand doses of hydromorphone [22] over the first 8



hours after surgery, then none further was required. The PCA was discontinued at 0700 the next morning and the patient was transitioned to oral hydrocodone [23] 5mg/acetameniphen [24] 325mg prior to discharge. The patient was also advised that ketorolac 12 IM supplemental pain control was available but it was not required for any break through pain control. A single dose of ondansetron [7] 4.0 mg IV was required for nausea about 9 hours post surgery.

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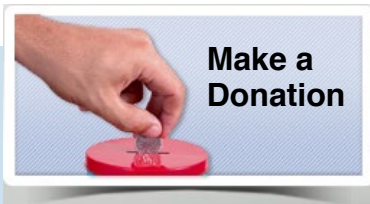
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Perhaps you were a patient and you were able to regain an important part of your life. Or, perhaps you are simply someone interested in medical research and seeking a new way to participate. Whatever the case, your generosity in helping to fund research is critical to our success - and much appreciated.

The Joint Implant Surgery & Research Foundation is a not-for-profit 501(c)(3) corporation. Your contributions enable scientific discoveries that will help future patients. Contributions over the years from people like you have helped to shape orthopaedics today.

### **Contributions**

Donations of any amount will immediately be put to use to fund ongoing and future orthopaedic research projects.

### **How to Give**

- Your gift of cash, securities or other negotiable assets is immediately put to use in our research.
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*For more information please visit our website at [www.jisrf.org](http://www.jisrf.org) or contact us at:*

### **Joint Implant Surgery & Research Foundation**

46 Chagrin Shopping Plaza, #118  
Chagrin Falls, OH 44022  
440.785.9154

# JISRF Creates Institutional Review Board

## JISRF's Board of Directors have approved the formation of an Institutional Review Board (IRB).

JISRF has a long rich history of conducting clinical/surgical research projects. There has been considerable interest in JISRF establishing a formal IRB Committee. The specific purpose of this IRB Committee is to assure, both in advance and by periodic review, that appropriate steps are taken to protect the rights and welfare of humans participating as subjects in a research study. JISRF's IRB Committee will attempt to ensure protection of subjects by reviewing research protocols and related materials. IRB protocol review assesses the ethics of the research and its methods, promotes fully informed and voluntary participation by prospective subjects capable of making such choices and seeks to maximize the safety of subjects.

JISRF has lectured and published on ethics and full disclosure since 1993. The Board sees the IRB Committee as a next logical step in interdisciplinary research and education while protecting the individual patients rights on full disclosure with regard to decision making of new technologies and potential conflict of interest in an ever changing health care environment.

Research grants, charitable contributions and revenue from our general fund support the IRB's work.



CREATING A GLOBAL ORTHOPAEDIC COMMUNITY

# WORLD ARTHROPLASTY CONGRESS

APRIL 16-18, 2015 | PARIS, FRANCE



COURSE CHAIRMEN: Jean-Noël Argenson, MD | Arlen D. Hanssen, MD | W. Norman Scott, MD, FACS | Jan Victor, MD

## Plan for Paris!

- The First-Ever Global Congress Dedicated Entirely to Hip & Knee Arthroplasty
- A Faculty of Orthopaedic Experts from Around the World
- Scientific Poster Sessions Featuring Global Advances in Hip & Knee Arthroplasty
- A unique and exciting social program featuring the finest that French and Parisian culture has to offer!

FOR REGISTRATION/INFO VISIT

[www.icjr.net/2015paris](http://www.icjr.net/2015paris)



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International Congress  
for Joint Reconstruction

Uniting Communities by Advancing Orthopaedic Education







ICJR

CME

"RELEVANT TOPICS WITH EXCELLENT PRESENTATIONS;  
GREAT COMBINATION OF TEACHING AND DISCUSSION"

-2013 MEETING ATTENDEE

# 6TH ANNUAL WINTER HIP & KNEE COURSE

JANUARY 16-19, 2014 | VAIL, CO

Vail Cascade

COURSE CHAIRMAN Raymond H. Kim, MD | Colorado Joint Replacement | Denver, CO  
COURSE CO-DIRECTORS Fred D. Cushner, MD | Insall Scott Kelly Institute | New York, NY  
Mark W. Pagnano, MD | Mayo Clinic | Rochester, MN

**FIRST 50 REGISTERED WILL RECEIVE AN  
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ICJR's 5th Annual Winter Hip & Knee Course was a great success with over 200 attendees and an internationally-renowned faculty. We look forward to another excellent program in 2014 and hope you will plan to join us!

FOR REGISTRATION/INFO VISIT

[www.icjr.net/2014vail](http://www.icjr.net/2014vail)

or contact us at 760-942-7859 or [info@icjr.net](mailto:info@icjr.net)

## REGISTRATION

	Early Bird
PHYSICIAN	\$745
INDUSTRY	\$645
ALLIED HEALTH Nurse, NP, PA, PT, PharmD	\$300
FELLOWS & RESIDENTS Must be ICJR Member	FREE

See website for details about registration fees & cancellations.





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ISK & European Knee Associates Conference

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OCTOBER 3-5, 2014 | NEW YORK, NY



## FEATURING

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- Live Surgeries
- Interactive Case Discussions
- Faculty of Global Orthopaedic Experts  
International Panel of Experts
- Scientific Poster Sessions

## COURSE CHAIRMEN

Jean-Noël Argenson, MD, PhD | Aix-Marseille University, Hospital Sainte-Marguerite

W. Norman Scott, MD | Insall Scott Kelly Institute

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# The First ICJR PAN PACIFIC ORTHOPAEDIC CONGRESS

JULY 16-19, 2014 | HILTON WAIKOLOA  
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COURSE CHAIRMEN: Douglas Dennis, MD | Arlen D. Hanssen, MD | Richard D. Komistek, PhD | W. Norman Scott, MD, FACS

Over 1000 attendees, integrating research interests across two continents and engaging clinicians and engineers in discussions about the future of orthopaedics.

#### TOPICS OF INTEREST

- Knee Mechanics
- Sensor Technology in Arthroplasty
- Patellar Resurfaces Issues
- Knee Disease: Non-Arthroplasty Option
- Optimal Patients for PKA
- Approaches to Patellofemoral, Meniscal and Articular Cartilage Surgery
- Current Treatments Involving Arthroscopic and Open Options for Sports-Related and Common Knee, Shoulder Injuries
- Arthroplasty Options for the Shoulder and Elbow
- OR and Practice Management Efficiencies
- Hip Mechanics

- Alternative Bearings in THA
- Computer Navigation in Joint Replacement
- Peri-prosthetic Fracture Management
- Ethnic, Gender, & Health Issues in Arthroplasty
- Hip Disease: Non Arthroplasty Options
- Hip Resurfacing
- FAI

#### SPECIAL!

- Discounted Room Rates (*limited number*)
- Pan Pacific President's Cup Tournament
- Awards for Poster and Oral Presentations
- Early Bird Rates, Register Early and Save!

FOR REGISTRATION/INFO VISIT

[www.icjr.net/2014hawaii](http://www.icjr.net/2014hawaii)





# Reconstructive Review

## Conflict of Interest Statement

*The following information will be published on each paper.*

Please check one or more if pertinent of the following:

- 1. No benefits or funds were received in support of this paper.
- 2. Benefits or funds were received in support of this paper either directly or indirectly.
- 3. Either family, institution I am associated with, or I have received benefits or funds either directly or indirectly regarding this paper.

Describe:

Author's Signature: \_\_\_\_\_ (Typed signature is valid for online submission.)

Joint Implant Surgery & Research Foundation

[www.jisrf.org](http://www.jisrf.org)

### Conflict of Interest Statement JISRF Orthopaedic Industry Affiliations (Past & Present)

Many Authors, Co-Authors, JISRF, or its Members have had affiliations past or present with one or more of these organizations.

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JISRF and the Reconstructive Review take disclosure very serious and often readers don't appreciate the indirect benefit writers receive in publications. Many of our contributors are officially associated with JISRF by the membership on study groups, editorial committee and or clinical / surgical advisors. JISRF is dependent on donations and commercial funding. The overall success of this funding benefits indirectly all that are associated with activities produced by JISRF.

### Disclosure for Authors

Article 1.  
 Sherif [1], Dipane [1], McPherson [1]  
 Article 2.  
 Shah [1], Gupta [1], Patel [1]  
 Article 3.  
 Morris [3], Berend [3], Adams [3], Lombardi [3]  
 Article 4.  
 Frye [1], Berend [3], Morris [3], Adams [3], Lombardi [3]  
 Article 5.  
 Beaufils [1], Thaunat [1], Pujol [1], Scheffler [1], Rossi [1], Carmont [1]  
 Article 6.  
 Fard-Aghaie [1], Citak [1], Correia [1], Haasper [1], Gehrke [1], Kendoff [1]  
 Article 7.  
 Sonohata [1], Waewsawangwong [1], Goodman [1]  
 Article 8.  
 Kouzelis [1], Georgiou [1], Megas [1]  
 Article 9.  
 Massai [1], Conteduca [1], Vadalà [1], Iorio [1], Basiglini [1], Ferretti [1]  
 Article 10.  
 Hillock [3], Keggi [3], Kennon [3], McPherson [3], Clyburn [3], Brazil [3], McTighe [3]  
 Article 11.  
 Zak [1], Hillock [3]





## Goytia Stackable Hohmann Retractors

Interlocking design helps to increase depth and leverage in hip exposure, particularly of the anterior acetabulum—especially useful with large patients

Designed by Robin N. Goytia, MD

- ▶ Custom fitted holes for interlocking retractors helps provide stability
- ▶ When "stacked", the increased lever arm of the retractor helps reduce fatigue
- ▶ Ideal for use with large patients where extra depth, leverage and force is needed

**NEW**

Sold in pairs: each item number is for 2 retractors

### PRODUCT NO'S:

4551 [Standard]  
Overall Length: 9.25"  
Blade Width: 19.5mm

4552 [Bent]  
Overall Length: 8.25"  
Blade Width: 19.5mm

4553 [Wide]  
Overall Length: 9.25"  
Blade Width: 43mm

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USA**



**NEW**

## Mueller Style Hip Instruments



### PRODUCT NO:

6865-01 [Flat Blade Osteotome]  
Overall Length: 11.125"  
Osteotome Width: 20mm

6865-02 [Femoral Head Dislocation Lever]  
Overall Length: 11.375"  
Scoop Dimensions: 25mm x 57mm

6865-03 [Narrow Curved Osteotome]  
Overall Length: 12"  
Osteotome Width: 9mm

6865-04 [Wide Curved Osteotome]  
Overall Length: 12"  
Osteotome Width: 16mm

6865-05 [Swan Neck Curved Gouge]  
Overall Length: 12"  
Gouge Width: 23mm

5350-CB [Cross Bar]

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# Dorr Hip Instruments

Designed by Lawrence D. Dorr, MD

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### Dorr Curved Hohmann Acetabular Retractor

Placed over the top of the piriformis, helps retract the gluteus medius.

### Dorr Narrow Bent Acetabular Retractors

Retracts the gluteus maximus off the trochanter and exposes the back of the greater trochanter. The long version is used with larger patients.

### Dorr Bent Hohmann Acetabular Retractor

Placed between the capsule and outer external oblique muscle to protect medial circumflex vessels. The tip engages the condyloid notch bone (teardrop). Helps retract soft tissues during acetabular exposure.



### Dorr Curved Blade Bent Hohmann Retractors

Used for both femoral exposure—placed around the femoral neck or beneath the top of the femoral head—and acetabular exposure—posterior superior of the acetabulum.

### Upward Double Bent Hohmann Retractor

Tapped into the ilium to help retract the femur for acetabular exposure.



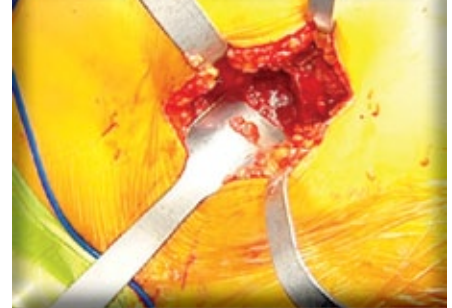
### Dorr Posterior Capsule and Sciatic Nerve Protection Retractors

Sits on the outer rim of the posterior inferior ishium to retract the posterior capsule for acetabular exposure and help to protect the sciatic nerve.



### Dorr Femoral Neck Elevators

Placed under the proximal femur to help expose the femoral head. The wide version is useful with large patients, while the narrow is useful when broaching or when the implant is in place.



### PRODUCT NO'S:

D6105 [Dorr Curved Hohmann Acetabular]  
Blade Width: 18.5mm  
Overall Length: 14"  
Depth from Handle: 4.5"

D6108 [Dorr Narrow Bent Acetabular—Long]  
Overall Length: 14.75"  
Depth from Handle: 6"  
Blade Width: 12.6mm

D6110 [Dorr Narrow Bent Acetabular]  
Overall Length: 15"  
Depth from Handle: 4.75"  
Blade Width at Widest: 12mm

D6112 [Dorr Bent Hohmann Acetabular]  
Overall Length: 14.5"  
Depth from Handle: 6"  
Blade Width: 21mm

### PRODUCT NO'S:

D6106 [Dorr Curved Blade Bent Hohmann]  
Overall Length: 13.5"  
Depth from Handle: 4.5"  
Blade Width: 40mm

D6107 [Dorr Curved Blade Double Bent Hohmann]  
Overall Length: 8.5"  
Depth from Handle: 5"  
Blade Width: 25mm

D6114 [Upward Double Bent Hohmann]  
Overall Length: 14"  
Depth from Flat Part of Handle: 5.5"  
Blade Width: 20.5mm

### PRODUCT NO'S:

Overall Length: 14"  
Depth from Handle: 6"  
Blade Width at Widest: 44mm

D6109-L [Dorr Posterior Capsule and Sciatic Nerve Protection Retractor—Left]

D6109-R [Dorr Posterior Capsule and Sciatic Nerve Protection Retractor—Right]

### PRODUCT NO'S:

D6111 [Dorr Wide Femoral Neck Elevator]  
Overall Length: 15"  
Depth from Handle: 2"  
Blade Width at Widest: 45mm

D6113 [Dorr Narrow Femoral Neck Elevator]  
Overall Length: 13.75"  
Depth from Handle: 2.25"  
Blade Width: 25mm

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