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ORIGINAL ARTICLE

Improving Pre-Operative Flexion in Primary TKA: A Surgical Technique Emphasizing Knee Flexion with 5-Year Follow-Up

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Abstract

This study prospectively reviews a consecutive series of 228 primary total knee arthroplasty (TKA) procedures utilizing a technique to optimize knee flexion. The main features include: (1)the use of a "patellar friendly" femoral component and reduced thickness patellar components, (2) patient individualized adjustment of the femoral component rotation set strictly to the anterior-posterior femoral axis, (3)a rigorous flexion compartment debridement to remove non-essential posterior femoral bone with a Z-osteotome, and (4)incorporation of a rapid recovery protocol with features to promote knee flexion.

Results were categorized into three groups: low pre-op flexion (90 degrees and below), regular pre-op flexion (91-125 degrees), and high pre-op flexion (126 degrees and above). Average flexion in the low flexion group improved by 20 degrees at 6 weeks, 28 degrees at 3 months, 31 degrees at 1 year, and 30 degrees at 5 years. In the regular flexion group, average flexion improved by 2 degrees at 6 weeks, 10 degrees at 3 months, 12 degrees at 1 year, and 13 degrees at 5 years. Finally, in the high flexion group, average flexion decreased by 7 degrees at 6 weeks, regained preoperative levels at 3 months, and increased by 3 degrees at 1 year and 4 degrees at 5 years.

In summary, a technique that emphasizes patellofemoral kinematics can consistently improve flexion in TKA in short and long-term follow-up.

Keywords: *Total knee arthroplasty, range of motion, high flexion, surgical technique, implant design, AP Axis*

Level of Evidence: *AAOS Therapeutic Study Level III*

Introduction

Primary total knee arthroplasty (TKA) is a very successful procedure that significantly improves quality of life. [11,15,28] The established goals of pain relief and preservation of patient function are accomplished in most patients in intermediate to long term follow up. [12,27] With the ever-increasing size of the baby boomer population, recent emphasis has been focused on improving patient outcomes, including knee flexion. [19,26] Newer concepts include less invasive surgical techniques, coordinated in-hospital and postoperative rapid recovery programs, and reduction in overall use of allied health resources. [6,7,13,20] These ideas are predicated upon the concept of reducing net patient costs, which ultimately reduces overall national healthcare costs. To be effective, any change in the short term goals must be consistently

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reproducible and must show an improvement compared to established methods in the long term.

This study prospectively reviews our work to maximize postoperative knee flexion in primary TKA. We utilize several concepts within our approach to high flexion which include: (1) the use of a "patellar friendly" high flexion design femoral component, (2) a modified surgical technique that places higher emphasis on patellofemoral alignment, (3) the removal of posterior femoral bone with a Z-osteotomy, and (4) a rapid recovery protocol that we have developed over a period of two years. This study reviews a consecutive series with this established protocol, prospectively followed to 5 years post-op.

Methods

The Vanguard® Complete Knee System (Biomet; Warsaw, Indiana) was utilized for primary total knee replacement patients treated by the senior author between October 2004 and February 2007. A cruciate retaining femoral component was used in all cases. When the posterior cruciate ligament (PCL) was incompetent, attenuated, or released, an anterior stabilized tibial component was implanted. When the PCL was intact, a standard polyethylene insert was used. If excess translation in flexion occurred, a congruent insert was utilized. All tibial components were modular metal base plates with a cruciate keel. An all-polyethylene 3 peg reduced thickness patellar dome was placed in all cases. Implants were cemented with Palacos® cement (Heraeus Kulzer GmbH; Wehrheim, Germany) without antibiotics.

All surgeries utilized a "less invasive surgery" technique with an anterior-medial incision. The deep arthrotomy started at the inferior-medial aspect of the tibial tubercle and typically ended 2.0 centimeters (cm) superior to the patella. Bone preparation employed reduced sized instrumentation (Microplasty™ , Biomet; Warsaw, Indiana) with posterior femoral referencing. An intramedullary guide system was used for distal femoral preparation and an extramedullary guide system was employed for proximal tibial preparation. A fixed "4 in 1" reduced size cutting block was used for the femoral cuts, with 5 cm long medial and lateral pins. For femoral component sizing and preparation, a modified posterior femoral condyle referencing system was used. Rotation of the femoral component strictly adhered to the anterior-posterior axis (AP axis) as defined by Whiteside. [3,21,30] The AP axis was carefully determined by utilizing a newly developed AP axis jig (figure 1). The base of the jig fit into the intercondylar notch at the most lateral aspect of the insertion of the PCL on the femur. The jig was then positioned into the base of the trochlear groove. The perpendicular line was marked on the cross bars of the jig with a blue marking pen (figure 2). The AP sizing jig employed a variable rotation axis to adjust femoral component rotation parallel to the marked blue line (figures 3a & 3b). Femoral component rotation was set from zero to nine degrees of external rotation.

Figure 1. Photograph of AP axis jig that is used intra-operatively to determine the anterior-posterior axis of the femur. The small triangle in the lower part of the jig is placed in the intercondylar notch at the most lateral insertion of the PCL ligament. The sliding upper portion of the jig is placed in the deepest portion of the trochlear groove. In cases of patellofemoral dysplasia, surgeon discretion was allowed for placement of the trochlear portion of the jig.

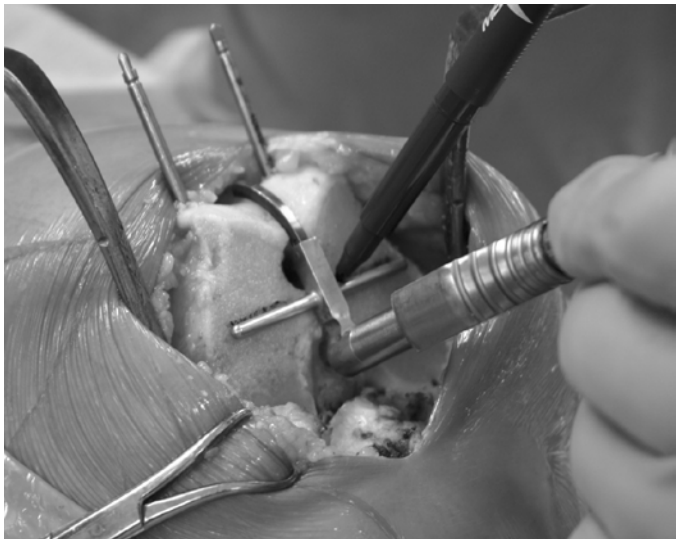

Figure 2. Intra-operative application of AP Axis Jig. As defined by Whiteside [30], the jig is placed at the most lateral portion of the PCL. The upper part lies in the patellar groove. The two side posts are perpendicular to the AP axis line. A marker is used to make a line on the distal cut of the femur. This defines the rotation for the femoral component.

Femoral component sizing was chosen to ensure that the lateral prosthetic trochlear flange was no thicker than the resected lateral trochlear bone. If the measured trochlear bone thickness was less than the 7 millimeter (mm) metallic flange thickness, the femur was downsized by one size. The goal was to place the anterior flange flush with the anterior femoral cortex. When needed, a femoral blend or small notch (up to 2 mm) cut was accepted. Posterior femoral condyle osteophyte removal was an important step. Any bone extending beyond the prosthetic femoral condyle was removed with a z-shaped osteotome to prevent flexion impingement (figures 4a & 4b).

Coronal plane balancing was accomplished with a trial femoral component and a tibial trial component without a keel. Releases were performed to achieve full knee exten-

Figures 3a-3b. Modified Femoral Sizing Jig.

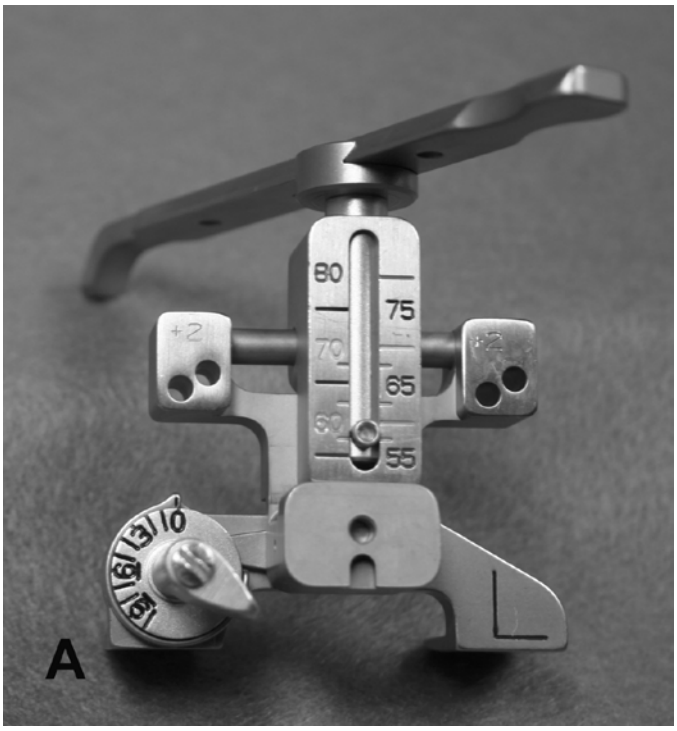

Figure 3a. Photograph of modified sizing jig. The jig uses the posterior femoral condyles for referencing. This jig uses posterior metallic pads to define the posterior femoral condyles. These pads are used to measure anterior to posterior height. However, instead of a fixed femoral rotation (usually between 3 to 5 degrees), this instrument utilizes a rotation dial to rotate the jig parallel to the reference line drawn in figure 2.

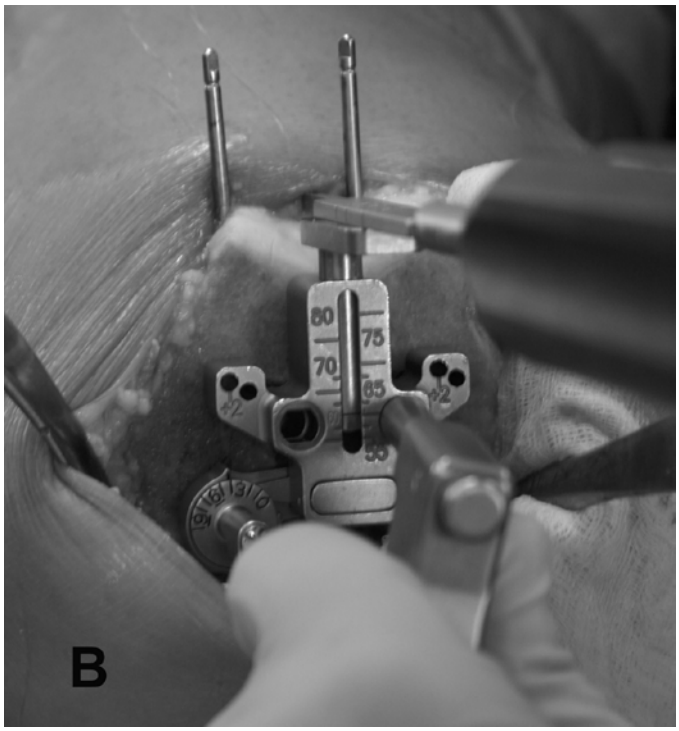

Figure 3b. Intra-operative placement of the AP sizing jig. Rotation is carefully set parallel to the rotation reference line. By using this method, we believe patellofemoral tracking is optimized for deep knee flexion. Notice in this case, external rotation was set at four degrees.

Figures 4a-4b. Z-osteotome for posterior femoral bone debridement.

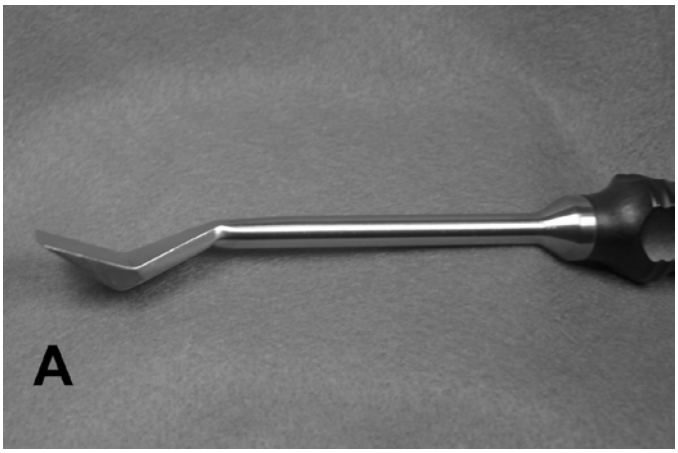

Figure 4a. Demonstrates design of Z-osteotome for posterior femoral condyle debridement. The current design shown is the 5th ideation. This tool allows removal of bone that would extend beyond metallic femoral condyles. The blade is short enough so as not to notch the posterior femoral cortex or damage the posterior femoral capsule.

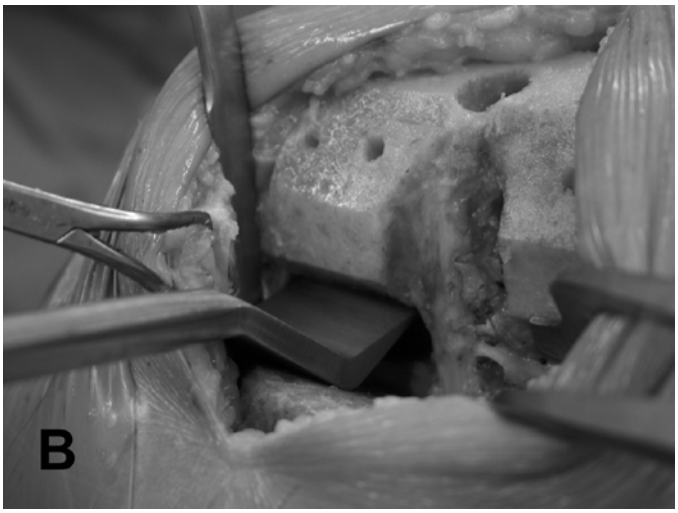

Figure 4b. Shows the application of Z-osteotome for posterior femoral bone debridement. The osteotome is placed on the cut posterior femoral condyle at a position just behind the end of the metallic femoral component. The cut bone is removed with a curved rongeur.

sion. Medial-lateral (ML) balance was tested in full extension and 90 degrees of flexion. Posterior tibial slope was individualized to parallel the medial compartment slope. Tibial component rotation was adjusted and marked at end flexion. This ensured optimal mating of the femoral and tibial components in deep flexion.

Patellar resurfacing technique strictly enforced restoration of patellar height without overstuffing. All patellar components were the modified thin design with reduced polyethylene thickness (see table 1). This assured that in every case the patella was not "overstuffed." Resurfacing also emphasized maximal patellar bone coverage from superior to inferior. The patellar dome was placed against the medial edge. Any remaining unresurfaced bone was

Table 1. Thickness Change between Standard and Modified Patellar Components

Patellar Diameter	Patellar Thickness (mm) Modified Thin Design	Patellar Thickness (mm) Standard Design
28mm	5.8	8.0
31mm	5.8	8.0
34mm	7.8	8.5
37mm	9.8	10.0

Figures 5a-5c. Technique of lateral patellar bone reduction. The unresurfaced patellar bone on the lateral side is removed to reduce lateral reticular tension.

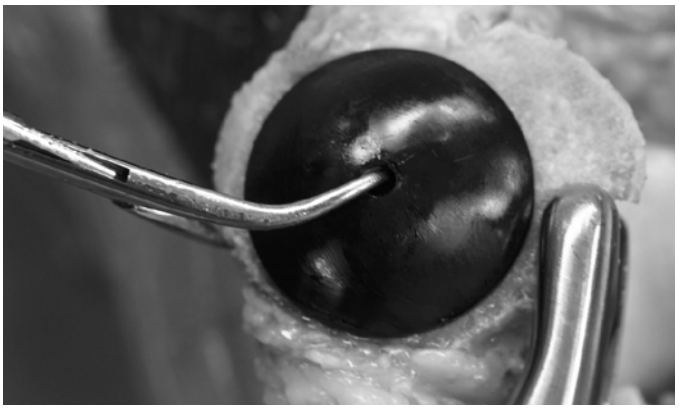

Figure 5a. Demonstrates placement of largest diameter low profile component which covers the patella from superior to inferior. The patella is placed next to the medial rim.

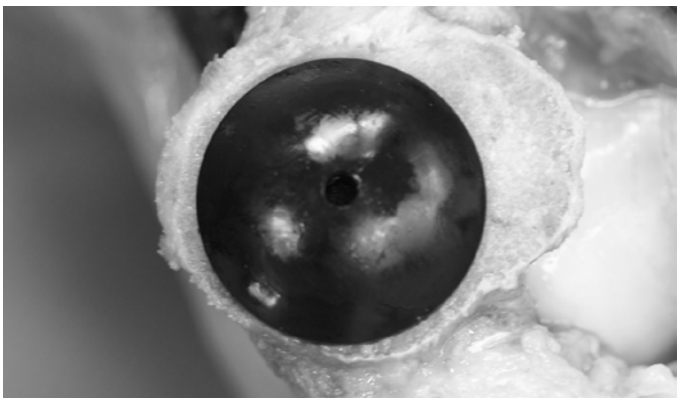

Figure 5b. The unresurfaced lateral patellar bone is dissected with an electrocautery and is removed with a large rongeur and trimmed with a small rongeur. With bone resection, lateral retinacular tissues about the patella are relieved.

Figure 5c. Shows the final result. The bone removal relaxes the peripatellar retinaculum and allows the patella to more easily track in the middle of the trochlear groove. In this case, 1.1cm of lateral patellar bone was removed.

removed with a lateral patellar bone reduction technique (figure 5).

Prior to closure, the pericapsular tissues were injected with a "joint cocktail" of 50cc with a 23 gauge spinal needle. The joint cocktail consisted of 100mg ropivicaine (Naropin®, Astra Zeneca; Wilmington, Delaware), 0.1mg epinephrine (Hospira; Lake Forest, Illinois), 80mg methylprednisolone acetate (DepoMedrol®, Pharmacia and Upjohn Co; Kalamazoo, Michigan), and 60mg ketorolac (Toradol®, Bedford Laboratories; Bedford, Ohio) mixed with sterile saline to achieve a volume of 50cc. Knee closure was performed at 90 to 95 degrees of flexion, including the skin. The skin was closed with a subcuticular closure with 4.0 Monocryl™ suture (Ethicon Inc; Somerville, New Jersey). A 7mm silastic drain was placed in every case. A pneumatic thigh tourniquet was used in every case, at a pressure of 275mm Hg. The tourniquet was released after skin closure when the sterile dressing was applied.

Postoperatively, a rapid recovery protocol was employed. [6] Surgeries were performed with a spinal anesthetic. Early ambulation, when possible, was started on the day of surgery. Inpatient physical therapy focused on gait training, safety, and home tasks, rather than knee flexion. Controlled passive motion (CPM) devices were never used. Patients were typically discharged between postoperative days 2 to 4. Outpatient physical therapy was prescribed for six to twelve weeks. Physical therapy was discontinued when the goals of end extension, flexion (typically 125 degrees), strength, and safety were consistently achieved by the patient.

Primary deep vein thrombosis (DVT) prophylaxis was pneumatic foot compression devices (Huntleigh FP 5000, Huntleigh Healthcare; Eatontown, New Jersey), thigh high graduated compression stockings (T.E.D® Stockings, Tyco Healthcare Group LP; Mansfield, Massachusetts), early ambulation, and oral aspirin (325mg) twice daily. Aspirin and graduated compression stockings were continued for six weeks. Patients with a known history of thrombophlebitis or pulmonary embolus (PE) were treated with 40mg subcutaneous enoxaparin sodium injection (Lovenox®, Sanofi-Aventis; Bridgewater, New Jersey) twice daily for three weeks, starting postoperative day one. Patients who were previously on warfarin (Coumadin®, Bristol-Meyers Squibb Co; Princeton, New Jersey) for atrial fibrillation were restarted on warfarin therapy.

Knee range of motion was measured in a 16-inch high chair, with the foot touching the floor. A standardized goniometer with 7-inch arms was employed. Routine patient follow up was scheduled at 6 weeks, 3 months, and annually. A decision for manipulation was made at the 6-week follow up interval. Pre-operative, operative, and post-op-

erative data was prospectively collected and maintained on a patient database in Microsoft Access® (Microsoft Corporation; Redmond, WA) and analyzed at regular intervals.

Results

Between October 2004 and February 2007, 201 patients (231 knees) underwent primary total knee arthroplasty utilizing Vanguard Complete Knee System components. Of these, three patients (3 knees) were excluded secondary to complications occurring prior to the six-week follow up visit. One patient died several weeks after hospital discharge of sepsis following emergency abdominal surgery. One patient required a revision for periprosthetic fracture after a fall and one required revision for posterior instability secondary to traumatic PCL rupture following a fall. Four patients (4 knees) did not return for follow up in our office. Three of these patients lived far from our office, decided to return to their primary orthopedic surgeon, and were doing well. One patient was a resident in a skilled nursing facility and declined to come in for office evaluation. This patient was satisfied with her knee replacement. Six patients (7 knees) had incomplete data. Two patients (3 knees) were missing 6-week data. Four patients (4 knees) were missing three-month data.

There were 148 female (65%) and 80 male (35%) patients. The mean age was 65 (range 20 to 98). The diagnosis was degenerative joint disease in 213 knees, post-traumatic arthritis in 9 knees, and rheumatoid arthritis in 6 knees. Deformity was absent in 62 knees, 42 knees had valgus deformities (defined as ≥ 12 degrees mechanical alignment), and 124 knees had varus deformities (defined as ≤ zero degrees mechanical alignment). Of the 228 procedures included in this study, 129 (57%) were performed on the right knee and 99 (43%) on the left knee.

Average pre-operative flexion was 114 degrees (range 70-140) and average pre-operative flexion contracture was 10 degrees (range 10 degrees of hyperextension to 32 degrees of flexion contracture). Average flexion achieved was 116 degrees at 6 week follow-up (range 65-142), 125 degrees at 3 month follow-up (range 80-152), 128 degrees at 1 year follow-up (range 85-152), and 128 degrees at 5 year follow-up (range 95-145). Average flexion contracture was 8 degrees at 6 weeks (range 0-22), 4 degrees at 3 months (range 0-24), 1 degree at 1 year (range 0-12), and 1 degree at 5 years (range 0-24).

Knee range results were then analyzed in three separate groups: low pre-op flexion (90 degrees or less), regular pre-op flexion (91-125 degrees), and high pre-op flexion (126 degrees and above). In the 15 cases with low pre-operative flexion, average preoperative flexion was 83 degrees. In this group, average pre-operative flexion contracture was 17 degrees (range 0-32). Average flexion achieved was 103 degrees at 6 weeks (range 80-125), 111 degrees at 3 months (range 80-130), 114 degrees at 1 year (range 85-125), and 113 degrees at 5 years (range 95-124). Average flexion contracture was 8 degrees at 6 weeks (range 0-16), 5 degrees at 3 months (range 0-12), 0 degrees at 1 year (range 0-0), and 1 degree at 5 years (range 0-10).

In 188 cases with regular pre-operative flexion, average pre-op flexion was 114 degrees. In this group, average pre-operative flexion contracture was 11 degrees (range 10 degrees of hyperextension to 30-degree flexion contracture). Average flexion was 116 at 6 weeks (range 65-142), 124 degrees at 3 months (range 102-142), 126 degrees at 1 year (range 105-150), and 127 degrees at 5 years (range 110-145). Average flexion contracture was 8 degrees at 6 weeks (range 0-22), 4 degrees at 3 months (range 0-24), 1 degree at 1 year (range 0-12), and 1 degree at 5 years (range 0-20).

Twenty-five cases were in the high pre-operative flexion group, with an average of 132 degrees. Pre-operative flexion contracture in this group was 6 degrees (range 0-15). Average flexion decreased at 6 weeks to 125 degrees (range 105-140), was equal to pre-operative flexion at 3 months (range 120-152), and increased to 135 degrees (range 120-152) at 1 year and 136 degrees (range 130-145) at 5 years. Average flexion contracture increased at 6 weeks to 8 degrees (range 0-14), but decreased to 4 degrees (range 0-13) at 3 months, 1 degree (range 0-10) at 1 year, and 1 degree (range 0-5) at 5 years.

Complications within this series included four patients (1.7%) with knee instability. One patient required revision to a salvage hinge prosthesis eight weeks post-operatively for global knee instability. Pre-operatively, the leg was moderately weak from a stroke. During the patient's rehabilitation, the knee became globally unstable including hyperextension. One patient experienced flexion instability with a subluxation event. This patient was revised with an anterior stabilized insert eleven weeks post-operatively, and subsequently has no instability. One patient experienced a subluxation event on the second post-operative day. This patient had in place an anterior stabilized insert, and was treated definitively with a controlled motion brace for six weeks. This patient has no residual instability. One patient experienced mild posterior subluxation (loose flexion gap) but decided against revision. Three knees (1.3%) required manipulation. All three patients achieved and maintained adequate flexion after manipulation.

There were seven (3%) incidents of wound complica-

tions. There was one case of a partial wound dehiscence after a fall that was repaired surgically, along with knee lavage. One patient had an evacuation of a deep hematoma. There were four cases of cellulitis that responded fully to antibiotic therapy. There was one irrigation and debridement for wound drainage and cellulitis that was concerning for a deep infection. This completely resolved following administration of intravenous antibiotics, and deep cultures were negative.

One patient required a repair of an extensor mechanism rupture following a fall. One patient had a DVT that responded to treatment with warfarin. One patient had a documented PE that was initially treated with heparin. The patient subsequently developed a small knee hematoma, and heparin was discontinued. She had no further problems following placement of an inferior vena cava filter. One patient required a blood transfusion prior to hospital discharge. One patient had a non Q-wave myocardial infarction on post-operative day two, and was treated medically following cardiac catheterization.

Discussion

In the following 20 years, the baby boomer population will mature and place significant pressure on the American Healthcare system. [26] Budgetary constraints will inevitably place restrictions upon reimbursement to hospitals, physicians, and allied healthcare professionals. In the realm of joint replacement surgery, we have already seen the curtailment of physical therapy visits allowed for Medicare and Medicaid patients.

At our center, we have focused on methods to deliver a cost effective, efficient "product" to patients requiring knee replacement surgery. The goal was to provide a knee replacement procedure that was "easy" on the patients and minimized perioperative care.

This study demonstrates that in the early post-operative period, knee flexion can be consistently maintained at 6 weeks and 3 months. At the 6-week follow up interval, the low pre-op flexion group gained an average 20 degrees of flexion, the regular pre-op flexion group gained an average 2 degrees of flexion, and the high pre-op flexion group lost 7 degrees of flexion. At the 3-month follow up the low pre-op flexion group maintained their increased flexion with an average increase of 28 degrees. The regular pre-op flexion group went on to gain an average of 10 degrees. The high pre-op flexion group returned to their average pre-operative flexion. Furthermore, these early gains in pre-operative flexion were maintained at 1 year and at 5 years in all groups. The improved flexion achieved in all groups we believe is attributable to several factors: (1)prosthetic design, (2)surgical technique, and (3)facilitated perioperative rehabilitation. [4,5]

The Vanguard® femoral component design is one that is considered "patellar friendly." The component is asymmetrical and laterally angulates the patellar groove by 6.5°. The lateral anterior flange thickness is relatively thin (7mm) which prevents an inordinate rising of the patella. Moreover, the trochlear groove is deep, which also prevents excess rising of the patella.

Another important factor was the ease of prosthetic sizing of the femur. The average incremental change in femoral component size is small (2.5mm). In addition, the AP to ML ratio of the femur is optimized to accommodate worldwide variations in distal femoral bony architecture. These two factors allowed more precise femoral sizing in both male and female populations without overhang.

The reduced thickness patellar components (modified thin design) allowed us to recreate patellar height without overstuffing. Overstuffing of the patellar height frequently occurs in smaller patients where the patellar thickness, not infrequently, measures 18-21mm. [22] This is a special problem to us given our diverse population within the United States. In this group, cutting the patella to a standard 15mm thickness and placing a typical 8mm patellar dome will increase patellar height and retinacular tension. Increased retinacular tension is perceived as pain, and, therefore, the patient will self-limit knee flexion range. [29] In this series, there was no case of overstuffing of the patellofemoral joint.

The other major factor optimizing knee flexion is surgical technique. [2,8,17,25,28,29] In this series, the described technique was developed over a period of three years and represents a significant paradigm shift for the authors. The current technique places emphasis on defining the patellofemoral plane of knee motion and then recreating that plane with the prosthetic femoral component. The tibial component is then mated in deep flexion to avoid flexion conflict. The above ideals do not displace the basic tenets of mechanical alignment and ligament balancing. Instead, coronal and sagittal knee balancing occurs after defining the flexion arc as determined by the AP axis method. The philosophy driving this technique is that the patellofemoral arc is an established patient parameter that, when created, provides the easiest route to knee flexion. [1,2,9,22] Any change in this plane makes patellofemoral balancing more difficult. Thus, recreating this plane will optimize patellar tracking and ultimately enhance knee flexion. In this series, femoral rotation was set between zero and nine degrees. Some would argue that a rotation from zero to three degrees is counterintuitive. This is thought to cause

lateral patellar maltracking, frequently necessitating a lateral retinacular release. However, in this series no formal lateral releases were required. This underscores the idea that native femoral rotation is not a fixed variable, but rather a range, following a bell curve. This is supported by the work of Poilvache, which describes natural femoral external rotation between 0.16 and 8.12 degrees. [24] We believe that postoperative rehabilitation is facilitated by not performing lateral releases. A lateral retinacular release is painful and causes significant knee swelling. This limits knee flexion and lengthens the rehabilitation period.

In this study a rapid recovery protocol was utilized. The protocol includes several techniques that we feel promote knee flexion. Closure of all soft tissues of the knee in flexion is known to improve flexion range and reduce hospital stay. [8,10,14,16,18] Although we cannot independently quantitate its effect, the injection of the pericapsular tissues with a "joint cocktail" does, in our opinion, facilitate early functional recovery. The pericapsular injection of pain medication and anti-inflammatory agents allowed our patients to transition routinely to oral narcotics and avoid intravenous patient controlled analgesia (PCA) pumps. We believe the combination of preemptive analgesia, intra-operative pericapsular injection, and post-operative oral analgesia maximized patient vigor, allowing patients to walk with confidence and participate in activities requiring greater knee flexion. [8,29]

During the post-operative period, patients continued with outpatient physical therapy. This was unchanged from our previous protocol. However, we received consistent feedback from our primary therapist regarding the ease with which patients regained flexion. Because of the varied geographical location of our patients, we could not objectively record the amount of physical therapy required for our patients. In some of our larger physical therapy clinics, the time to discharge from physical therapy has decreased significantly, from a typical 10-14 weeks to just 4-10 weeks currently.

In this series, a considerable number of patients (N=4) suffered posterior flexion instability. For the most part, this can be explained by surgeon error. Prior to this series, the operating surgeon implanted exclusively posterior stabilized knee implants for a five year period. The change to a cruciate retaining construct was based upon disenchantment with patient complaints of knee crunch, clicks, and rattling in posterior stabilized knees. In this series, we accepted more generous flexion gaps than we should have allowed (a posterior stabilized bias). Furthermore, in the early part of this series, anterior stabilized tibial inserts were not yet available. We believe the combination of anatomic tibial slope, lax flexion gaps, and lack of anterior stabilized inserts was the cause of flexion instability. Based upon this experience, we more aggressively utilize the anterior stabilized insert if the PCL is at all attenuated. [9,23]

In summary, this study shows that knee flexion after TKA can be improved consistently without utilizing excess allied healthcare resources. We realize this is just one method and other prosthetic designs and techniques may accomplish similar goals. However, we emphasize several ideas that can be universally applied to improve flexion. First, the surgeon should never overstuff net patellar height. Increased patellar height increases retinacular tension, which can reduce knee flexion. Second, adjusting tibial component rotation with the knee at end flexion in our experience is a helpful technical point to promote knee flexion. Lastly, adjusting femoral component rotation using only the AP axis is an acceptable technique. By recreating the sagittal arc of the knee via the AP axis technique, we have found reproducible knee flexion without incurring significant kinematic conflict or patellar maltracking. Furthermore, this technique can be utilized in less invasive incisions where other femoral landmarks are frequently obscured. We feel these techniques deserve further evaluation and will continue to follow this series of patients to determine long term outcomes for this prosthesis design, surgical technique, and recovery protocol.

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