Surgical Technique

Computer-assisted Sliding Medial Condylar Osteotomy to Achieve Gap Balance in Varus Knees During TKA

Arun B. Mullaji FRCS Ed, MCh Orth, MS Orth,
Gautam M. Shetty MS Orth

Published online: 3 January 2013
© The Association of Bone and Joint Surgeons® 2013

Abstract

Background Extensive posteromedial release to correct severe varus deformity during TKA may result in medio-lateral or flexion instability and may require a constrained implant. We describe a technique combining computer navigation and medial condylar osteotomy in severe varus deformity to achieve a primary goal of ligament balance during TKA.

Description of Technique The goal of this procedure was to achieve mediolateral gap balance in varus knees with rigid, recalcitrant medial contracture, with or without

excessive lateral laxity, not amenable to extensive medial soft tissue releases. A sliding medial condylar osteotomy (SMCO) was performed under navigation guidance and the condylar block internally fixed using cancellous screws.

Methods We prospectively evaluated mediolateral laxity, Knee Society scores, and knee ROM after SMCO in 12 varus arthritic knees in 11 patients (five men, six women) undergoing TKA with a minimum followup of 2 years (mean, 2 years; range, 2–2.5 years).

Results The degree of mediolateral knee laxity improved from Grade 2 (in four knees) and Grade 3 (in eight knees) preoperatively to Grade 1 (< 5 mm) in all knees at last followup. Mean Knee Society score improved from 30 (range, 10–54) to 92 (range, 86–100). Mean knee flexion improved from 106° (range, 90°–120°) to 112° (range, 100°–124°), and no knee had any extensor lag or residual flexion deformity (> 5°). Three knees had asymptomatic fibrous union at the osteotomy site.

Conclusions Computer-assisted SMCO in varus knees with recalcitrant medial contracture achieves improved mediolateral stability and knee function after TKA. Our technique uses navigation to accurately reposition the medial condylar block to equalize medial and lateral gaps, thereby ensuring a stable well-aligned knee without deploying constrained implants.

Level of Evidence Level IV, therapeutic study. See Instructions for Authors for a complete description of levels of evidence.

One of the authors (ABM) is a consultant for DePuy India (Mumbai, India). The other author (GMS) certifies that he, or a member of his immediate family, has no funding or commercial associations (eg, consultancies, stock ownership, equity interest, patent/licensing arrangements, etc) that might pose a conflict of interest in connection with the submitted article.

All ICMJE Conflict of Interest Forms for authors and *Clinical Orthopaedics and Related Research* editors and board members are on file with the publication and can be viewed on request.

Clinical Orthopaedics and Related Research neither advocates nor endorses the use of any treatment, drug, or device. Readers are encouraged to always seek additional information, including FDA approval status, of any drug or device before clinical use.

Each author certifies that his or her institution approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.

This work was performed at Breach Candy Hospital, Mumbai, India.

A. B. Mullaji (✉)
The Arthritis Clinic, 101, Cornelian, Kemp's Corner,
Cumballa Hill, Mumbai 400036, India
e-mail: arunmullaji@gmail.com

A. B. Mullaji, G. M. Shetty
Department of Orthopaedic Surgery,
Breach Candy Hospital, Mumbai, India

Introduction

Sequentially releasing medial soft tissue structures in a varus arthritic knee during TKA is one technique to correct deformity and achieve a well-balanced knee [19, 26].

However, some knees with severe or rigid varus deformities may require extensive soft tissue releases, including the need to subperiosteally elevate the tibial attachment of the superficial medial collateral ligament (MCL) [5, 19, 24, 26]. This carries the risk of mediolateral instability (if there is overrelease or inadvertent total detachment of the superficial MCL) and results in the flexion gap exceeding the extension gap, both of which increase the potential need for a constrained prosthesis [14]. On the other hand, leaving the knee with mediolateral imbalance due to inadequate medial release may lead to long-term instability, polyethylene wear, and potential loosening of tibial component from persistent adductor thrust [22].

Engl and Ammeen [6] described the use of a wafer-thin medial epicondylar osteotomy (MEO) in conventional TKA to correct soft tissue contractures in varus knees during TKA. They detached the MCL with a sliver of the medial epicondyle that included the adductor magnus tendon insertion; it was allowed to find its own position and was not internally fixed [6]. Our approach to achieving deformity correction and mediolateral soft tissue balance in recalcitrant varus deformities during TKA is to perform a sliding medial condyle osteotomy (SMCO) with the guidance of computer navigation.

The patients in this series were of Asian origin. Knee arthritic deformities in these patients are frequently confounded by an extraarticular deformity, such as excessive coronal bowing of the femur [18, 27]. This adds to the complexity and difficulty of achieving deformity correction and mediolateral soft tissue balance during TKA, especially in the presence of substantial lateral laxity [17, 20]. Hence, SMCO was used in rigid, recalcitrant varus deformities during TKA not amenable to full correction of alignment to normal and/or mediolateral soft tissue balance despite extensive release of medial soft tissue structures.

We describe our technique combining computer navigation and SMCO to achieve equipoise with the lateral soft tissue structures and report the results of this technique in a series of varus arthritic knees by answering the following questions: (1) Did the procedure restore mediolateral ligament balance? (2) Did the procedure improve patient function? And (3) what preoperative radiographic features were common to knees that required SMCO during computer-assisted TKA for varus deformities?

Surgical Technique

The indication for SMCO was rigid, recalcitrant varus deformities during TKA not amenable to full correction of alignment to normal and/or mediolateral soft tissue balance despite extensive release of medial soft tissue structures (excluding the superficial MCL and the pes anserinus) and

a reduction osteotomy. The only contraindication was a small-sized distal femur where performing an SMCO would increase the risk of intraoperative fracture of the medial femoral condyle.

Under tourniquet, the knee was approached using an anterior longitudinal incision and a medial parapatellar arthrotomy. The image-free Ci Navigation System (Brainlab, Munich, Germany) was used to perform navigation during TKA [7, 15]. A cemented, posterior cruciate-substituting design (Press-Fit Condylar[®] Sigma[®]; DePuy International, Warsaw, IN, USA) was used for all cases and all patients had resurfacing of the patella. During navigation, registration was performed in standard fashion after insertion of two pins in the proximal tibia and distal femoral shaft to which arrays with three reflector spheres were affixed. The mechanical axis of the lower limb was obtained by navigation, registering the center of femoral head, both malleoli, the center of the intercondylar notch, and the center of the tibial plateau; the severity of deformity was recorded. The surgical aim of navigated TKA was to achieve a final coronal plane limb alignment within 1° from neutral in full extension, a mediolateral soft tissue gap difference of less than 1 mm in full extension and less than 2 mm at 90° flexion, and a flexion-extension gap difference not exceeding 2 mm. Proximal tibial and distal femoral cutting blocks were navigated into position and the tibial resection performed first. The thickness of tibial and distal femoral cuts was adjusted depending on the degree of deformity and severity of lateral laxity. The greater the deformity and laxity were, the lesser was the cut thickness (6–7 mm each in severe cases). Using the gap-balancing technique, the degree of soft tissue release was governed by the amount of soft tissue tightness assessed using a tensioning device and medial and lateral gap imbalance as quantified by the computer. Based on the severity of coronal plane deformity and the amount of mediolateral soft tissue imbalance in full extension, a graduated stepwise medial soft tissue release was performed to achieve full correction and good mediolateral balance (Fig. 1). If equipoise was not achieved with the releases, a reduction osteotomy of the medial aspect of the proximal tibia was performed. Reduction osteotomy involved removing the exposed bone from medial proximal tibial surface after downsizing and lateralizing the tibial component to remove the tenting effect of this bone on medial ligamentous structures [4, 19].

In case of recalcitrant varus deformities, the computer displayed the amount of residual deformity and precise amount of medial and lateral gaps (Fig. 2A) after placing equal tension using the tensioner device in full extension. The difference was noted, after which distal femoral resection was performed, taking care not to overresect bone if there was a large deformity or increased laxity. The AP

Fig. 1 A graduated stepwise algorithm for medial soft tissue release in varus deformities during TKA is shown.

cutting block was then navigated into position and flexion gap assessed using a spacer block corresponding to the larger lateral gap. Modification in the size and placement of the femoral component was sometimes required here to balance the flexion and extension gaps and this was performed in virtual fashion by the software. The AP, chamfer, and notch cuts were completed. Rigid residual varus deformity was then dealt with by performing an SMCO. Our threshold for performing SMCO for ligament imbalance was a mediolateral soft tissue gap difference exceeding 2 mm in full extension and at 90° flexion and a flexion-extension gap difference exceeding 2 mm with or without a residual varus deformity of greater than 3° despite extensive soft tissue release and a reduction osteotomy. The aim was to achieve limb alignment within 1° of neutral and a mediolateral disparity of not more than 0.5 mm in full extension as measured by navigation at the end of surgery. The SMCO was performed in the following manner (Fig. 2).

Osteotomy was performed in the sagittal plane using a reciprocating saw, with the knee in 90° flexion. The cut was started 5 mm lateral to the medial edge of the bony medial condyle (outlined on bone with marking pen), continued proximally and slightly obliquely in a superomedial direction, and exited distal to the adductor tubercle (Fig. 2B).

The amount of difference between the medial and lateral gaps previously recorded in full extension was marked using electrocautery on the distal part of the bone block using a measuring scale (Fig. 2B). The chamfer cuts were also marked on the block so that it could fit within the contours of the femoral component during fixation.

The detached bone block was then held by sutures passed through its soft tissue attachment so that the block

could be maneuvered into position without damaging it (Fig. 2C). The thickness of the condylar block should have enough bone stock to securely reattach it using screws yet not so thick as to compromise the support afforded by the remaining medial condyle.

The marked amount of bone on the distal part of the block was excised using a bone cutter (Fig. 2B).

With the trial components in position, the medial condylar block was gently pulled distally into position (Fig. 2D) using the sutures and a periosteal elevator and the final soft tissue tension and alignment reconfirmed with navigation with the knee in full extension and at 90° flexion.

During cementing of the final components, cement was not applied on the medial 1 cm of the medial condyle of the femoral component to avoid excessive cement seeping into the osteotomy site. However, cement was applied on the entire medial femoral condyle bone surface. Once all components were cemented in place, any excess cement at the osteotomy site was removed and the final insert was placed on the tray.

After the cement had cured, the joint was reduced and the medial condylar block was internally fixed using screws with the knee in 45° flexion (Fig. 2E). The block was first held in place using a large towel clip, taking care that the block was within the flange of the femoral component. It was firmly apposed to the medial femoral condyle and temporarily fixed using a single 2-mm K-wire. The block was then fixed using two to three 4-mm fully threaded cancellous screws with washers. The final limb alignment and soft tissue balance were confirmed using navigation.

Postoperatively, full weightbearing ambulation in a long-leg knee brace was allowed within 24 hours and quadriceps strengthening exercises initiated. However, the

Fig. 2A–E (A) The difference (Distance CD – Distance AB) between the medial gap (Distance AB) and the lateral gap (Distance CD) in full extension is measured intraoperatively using either navigation or a measuring ruler. (B) The plane of osteotomy (dotted arrow), which starts 5 mm lateral to the medial edge of the bony medial femoral condyle, continues proximally and slightly obliquely in a superomedial direction and exits distal to the adductor tubercle (asterisk). Distance XY is the amount of difference between the medial and lateral gaps (Distance CD – Distance AB) that must be excised to distalize the condylar block. (C) An intraoperative photograph shows the condylar block (arrow) after osteotomy held and controlled using sutures passed through its soft tissue attachment. (D) The condylar block is shifted distally (arrow) after the prosthesis has been implanted and fixed with cancellous screws. (E) An intraoperative photograph shows the condylar block internally fixed after cementing the final components using three cancellous screws.

patient was not allowed knee flexion for 2 weeks postoperatively. After 2 weeks, the patient was allowed to remove the brace three to four times a day and perform gentle active knee flexion as tolerated. The brace was discontinued at 1 month postoperatively and the patient was allowed unrestricted activity. Knee radiographs were performed at 6 weeks postoperatively to confirm stable fixation and healing at the osteotomy site.

Patients and Methods

We prospectively collected data on and retrospectively analyzed all 17 patients who underwent computer-assisted

TKAs in which the senior surgeon (ABM) had performed an SMCO for varus arthritic knees since he first started using it in October 2009 until October 2010. The indication for TKA was primary osteoarthritis in all knees. We excluded five patients with a followup of less than 2 years from the date of surgery. None were excluded due to incomplete clinical or radiographic records. The exclusions left 12 knees in which SMCOs were performed with a minimum followup of 2 years. These 12 SMCOs were performed in 11 patients (five men, six women) with a mean age of 66 years (range, 52–80 years) and a mean BMI of 28 (range, 23–36) at the time of surgery. The minimum followup was 2 years (range, 2–2.5 years). No patient was lost to followup. No patients were recalled

specifically for this study; all data were obtained from medical records and radiographs.

Standing, full-length (hip-to-ankle) weightbearing radiographs, weightbearing AP knee radiographs, and lateral knee radiographs were obtained in all patients pre- and postoperatively. Both full-length and knee radiographs were taken preoperatively and at 6 weeks postoperatively and were used by one of us (GMS) who was not the treating surgeon to measure various radiographic parameters for the study (Table 1). The degree of pre- and postoperative knee deformity was measured as the hip-knee-ankle (HKA) angle on standing full-length radiographs as the angle between the mechanical axis of the femur (center of the femoral head to the center of the knee) and the mechanical axis of the tibia (center of the knee to the center of the ankle) (Fig. 3). Angular measurements on full-length radiographs are reportedly reliable [25]. The amount of femoral bowing in the coronal plane was measured by the method described by Yau et al. [27] as the angle made by the middiaphyseal lines of the proximal ½ and distal ½ of the femoral shaft (Fig. 3A). Bowing was considered clinically important if the angulation was greater than 5° in the coronal plane. We also noted lateral joint space opening on full-length radiographs, which indicated lateral soft tissue laxity (Fig. 3A). The amount of lateral joint space opening was quantified as the joint divergence angle [20] measured as the angle made by the distal femur and the proximal tibial cut plotted perpendicular to the femoral and tibial mechanical axes (Fig. 3A). On postoperative standing full-length radiographs (Fig. 3B), the coronal alignment of femoral and tibial components respective to their mechanical axes was measured. On postoperative lateral radiographs, the sagittal alignment of the femoral component with respect to the anatomic axis of

Fig. 3A–B (A) A preoperative standing, full-length hip-to-ankle radiograph shows a left knee varus arthritic deformity of 30°; excessive bowing of the femoral shaft in the coronal plane (7°), measured as the angle made by the middiaphyseal lines (white lines) of the proximal ½ and distal ½ of the femoral shaft; and substantial lateral joint space opening or joint divergence angle (27°), measured as the angle (angle ABC) made by the distal femur and the proximal tibial cut plotted perpendicular to the femoral and tibial mechanical axes, indicating excessive laxity of lateral soft tissue structures. (B) A postoperative standing, full-length hip-to-ankle radiograph of the same patient shows a near-neutral mechanical alignment of the limb after a TKA with SMCO. It was not required on the right knee performed at the same sitting.

Table 1. Radiographic data of the study group

Patient	Preoperative HKA angle (°)	Femoral bowing (°)	Joint Divergence angle (°)	Postoperative HKA angle (°)	MFCA (°)	MTCA (°)	Femoral flexion (°)	Tibial slope (°)	Tibial insert thickness (mm)
1	171	1	16	181	91	90	93	87	12.5
2 (left)	159	5	17	177	86	92	91	90	15
2 (right)	155	8	20	179	92	89	93	88	12.5
3	164	0	20	180	88	92	97	90	12.5
4	165	6	21	180	92	90	95	88	12.5
5	160	9	21	179	90	91	94	90	12.5
6	165	0	22	180	92	90	94	88	12.5
7	165	8	24	178	93	94	95	90	15
8	150	7	27	178	88	88	98	91	12.5
9	144	12	29	175	84	88	93	87	17.5
10	158	5	31	179	90	90	90	88	17.5
11	150	5	35	177	90	90	94	86	15
Mean ± SD	159 ± 7	5 ± 3.6	24 ± 6	178 ± 1.5	90 ± 3.0	90 ± 1.8	94 ± 2.5	89 ± 1.5	

HKA = hip-knee-ankle; MFCA = medial femoral condylar angle; MTCA = medial tibial condylar angle.

the distal femur and the tibial slope with respect to the anatomic axis of the proximal tibia were measured. At and beyond 3 months of followup, only AP and lateral knee radiographs were taken and were used to determine union at the osteotomy site. Fibrous union was present if a gap could be seen between the medial femoral condyle and the osteotomized block and there was no mobility of the block or excess medial laxity of greater than 5 mm on clinical examination at 3 months postoperatively. All digital radiographic images were analyzed using ImageJ image processing and analysis software (Version 1.41; NIH, Bethesda, MD, USA).

One of us (ABM) evaluated all patients clinically for grade of mediolateral laxity, Knee Society score [10], knee ROM (measured using a goniometer), flexion deformity, and extensor lag pre- and postoperatively (Table 2). Mediolateral laxity with knee in full extension was assessed clinically based on grades from the Knee Society score (0–5 mm, 5–10 mm, > 10 mm) [10].

Patients were followed up at 2 and 6 weeks postoperatively when a clinical examination was performed to determine the knee ROM or any residual extensor lag or flexion deformity requiring further physiotherapy. Subsequently, the patients were followed up at 3 months, 6 months, and 1 year and every year thereafter. We used the clinical data recorded at last followup (with a minimum followup of 2 years) regarding grade of mediolateral laxity, knee score, knee ROM, residual flexion deformity, and residual extensor lag for analysis.

Results

The execution of SMCO restored mediolateral ligament balance and improved patient function. The degree of mediolateral knee laxity improved from Grade 2 (in four knees) and Grade 3 (in eight knees) preoperatively to Grade 1 (< 5 mm) in all knees at last followup (Table 2). The mean preoperative Knee Society score of 30.2 (range, 10–54) improved to 92 (range, 86–100) at last followup. The mean preoperative knee flexion of 106° (range, 90°–120°) improved to 112.5° (range, 100°–124°) postoperatively. No patient had residual extensor lag or flexion deformity when the knee was clinically examined in full extension at last followup (Table 2). All patients were able to independently rise from a chair, walk, and climb stairs without any walking aid at last followup. None of the patients had any complications related to the procedure. Asymptomatic fibrous union in three knees and complete bony union in nine knees were noted radiographically at the osteotomy site at last followup.

Three radiographic features on preoperative full-length radiographs were common to the knees requiring the procedure of SMCO. Eleven of 12 limbs had a preoperative varus deformity of 15° or more or HKA angle of 165° or less (range, 144.3°–165°), six of 12 limbs had substantial femoral bowing of greater than 5° in the coronal plane with a mean bowing of 8.0° (range, 6°–12°), and 10 of 12 limbs had a joint divergence angle of 20° or more indicating considerable lateral joint space opening (Table 1).

Table 2. Function data of the study group

Patient	Preoperative Knee Society score (points)	Preoperative maximum knee flexion (°)	Preoperative mediolateral laxity*	Postoperative Knee Society score (points)	Postoperative maximum knee flexion (°)	Postoperative mediolateral laxity*
1	54	90	Grade 2	96	108	Grade 1
2 (left)	25	110	Grade 2	92	110	Grade 1
2 (right)	25	110	Grade 2	92	110	Grade 1
3	32	100	Grade 2	96	112	Grade 1
4	37	120	Grade 3	95	110	Grade 1
5	40	110	Grade 3	95	124	Grade 1
6	36	100	Grade 3	90	120	Grade 1
7	35	90	Grade 3	88	106	Grade 1
8	22	100	Grade 3	90	110	Grade 1
9	10	110	Grade 3	86	100	Grade 1
10	32	110	Grade 3	100	120	Grade 1
11	15	120	Grade 3	90	118	Grade 1

* Grade 1 = < 5 mm; Grade 2 = 5–10 mm; Grade 3 = > 10 mm.

Discussion

Computer navigation allows for precisely measuring limb alignment and the difference between medial and lateral gaps, modifying the femoral component size and virtual component placement to balance flexion and extension gaps [7, 16, 24]. These functions are invaluable in SMCO where the aim is to reduce mediolateral imbalance by accurately distalizing the medial epicondyle and to achieve equipose with the lateral soft tissue structures. We described a novel technique combining computer navigation and SMCO to achieve equipose with the lateral soft tissue structures and reported the results of this technique in a series of varus arthritic knees by answering the following questions: (1) Did this procedure restore mediolateral ligament balance? (2) Did this procedure help to improve patient function? And (3) what preoperative radiographic features were common to knees that required SMCO during computer-assisted TKA for varus deformities?

Our study has a few limitations. First, this is a small case series with 12 TKAs that had undergone SMCO. Since this procedure was used sparingly in recalcitrant varus deformities and the senior author started performing this procedure in October 2009, a small number of knees were available for analysis with a minimum followup of 2 years. Second, our threshold for performing SMCO for ligament imbalance was a mediolateral soft tissue gap difference of greater than 2 mm in full extension despite extensive soft tissue release. Reports suggest mediolateral gap balance may undergo change postoperatively with either reduction in lateral laxity [23] or increase in medial laxity over a period of time [2]. Hence, how much lateral laxity or medial tightness is acceptable at the end of surgery is not clear and the threshold for performing an SMCO depends on the surgeon. Although our threshold needs further confirmation, our short-term results show SMCO performed using our threshold can achieve a stable, well-aligned knee. Third, although we performed SMCO under navigation guidance, which offers several advantages, a learning curve is involved and the surgeon must be well versed with using navigation. Hence, SMCO can be performed conventionally (where the difference in medial and lateral gaps and the required amount of distal displacement of the osteotomized block are measured using a measuring ruler) if the surgeon is not well versed with the use of navigation. Finally, postoperative ligament balance was clinically assessed based on grades of medial/lateral stability from the Knee Society score [6]. Although this method is relatively less objective when compared to other methods such as stress radiographs, the objective subscale (consisting of clinical stability, malalignment, lag and flexion contracture) of the Knee Society score reportedly is consistent and reliable with limited confirmation [21].

Clinically, our patients had restored mediolateral stability and function at last followup with the ability to walk, arise from a chair, and climb stairs without support. Similarly, Engh and Ammeen [6] reported restoration of function with their technique of MEO in 95% of their patients at a mean followup of 2.7 years. However, although the mean postoperative knee flexion achieved by their patients (111°) was similar to ours (mean, 112°), the minimum flexion achieved was 53° , with 21% (nine knees) showing a postoperative mediolateral laxity of greater than 6° [6]. This difference in results could be due to the inclusion of preoperatively ankylosed knees in their series and the fact that they did not intentionally fix the epicondylar fragment after osteotomy, resulting in bony union of the epicondylar fragment in only 54% of the knees and subsequent postoperative mediolateral laxity. We also had three cases of fibrous union (all asymptomatic) in our series, which were in earlier knees in which the bone was osteoporotic and the purchase of the screws was probably inadequate for early mobilization. Hence, we now keep the brace for 2 weeks after surgery without flexing the knee and have seen bony union occurring in them without loss of ROM.

Eleven of 12 knees that underwent SMCO in our series had a preoperative varus deformity of 15° or more, six of 12 knees had excessive femoral bowing in the coronal plane, and 10 of 12 knees also had substantial lateral joint space opening (indicating severe lateral laxity) on full-length radiographs. These knees would have otherwise warranted extensive release of the medial structures (including the superficial MCL) to achieve deformity correction. Hence, the above three features when seen on preoperative radiographs should alert the surgeon to the possible need for an SMCO (Fig. 3). The main indications for performing an MEO in the conventional TKA series of Engh and Ammeen [6] were a fixed varus deformity with a flexion contracture whereas we used SMCO as an alternative to extensive medial soft tissue (superficial MCL and pes anserinus) release for unbalanced gaps during TKA due to recalcitrant contracture of the posteromedial soft tissues, with or without associated excessive laxity of the lateral soft tissues, often coupled with an extraarticular deformity.

There are some alternatives to our technique to deal with rigid recalcitrant varus deformities with or without lateral laxity. Fractional lengthening or partial release of the superficial MCL at the tibial attachment [1, 26] carries the risk of inadvertent rupture or complete detachment of the ligament. Complete release of the superficial MCL from its tibial attachment, with or without reattachment [9, 11, 12], is an imprecise technique that simultaneously increases the medial gap in extension and flexion [16], leading to potential medial instability or laxity. For surgeons balancing the flexion gap by placing the AP cutting block parallel to the

tibial cut, it would require internal rotation of the femoral component to balance the flexion gap medially, with possible adverse consequences for patellar tracking [8]. Lastly, constrained implants in such complex varus deformities have been reported to give good short- and intermediate-term functional outcomes and survival rates after primary TKA [3, 9, 11, 13, 14]. However, in view of the prohibitive cost involved and complexity of revision surgery if required, we reserve constraint implants only for arthritic knees with complex deformities associated with substantial instability, especially in elderly, sedentary patients [9, 14]. These risks are mitigated by osteotomizing the medial condyle as the superficial MCL maintains its integrity.

Computer-assisted SMCO helps to accurately reposition the medial condylar block based on the amount of difference between the medial and lateral extension gaps, thereby ensuring a stable knee in extension. We believe it a reasonable alternative to extensive medial soft tissue release or conventional MEO in severe and rigid varus deformities to achieve optimal soft tissue equipoise and allow one to confer stability to the knee without recourse to highly constrained prostheses in complex varus deformities.

References

- Bellemans J. Multiple needle puncturing: balancing the varus knee. *Orthopedics*. 2011;34:e510–e512.
- Bellemans J, D'Hooghe P, Vandenuecker H, Van Damme G, Victor J. Soft tissue balance in total knee arthroplasty: does stress relaxation occur perioperatively? *Clin Orthop Relat Res*. 2006; 452:49–52.
- Cheung KW, Yung SH, Chiu KH. Primary total knee replacement using constrained condylar prosthesis in knee with severe varus deformity. *Hong Kong J Orthop Surg*. 2002;6:65–68.
- Dixon MC, Parsch D, Brown RR, Scott RD. The correction of severe varus deformity in total knee arthroplasty by tibial component downsizing and resection of uncapped proximal medial bone. *J Arthroplasty*. 2004;19:19–22.
- Engh GA. The difficult knee: severe varus and valgus. *Clin Orthop Relat Res*. 2003;416:58–63.
- Engh GA, Ammeen D. Results of total knee arthroplasty with medial epicondylar osteotomy to correct varus deformity. *Clin Orthop Relat Res*. 1999;367:141–148.
- Fickert S, Jawhar A, Sunil P, Scharf HP. Precision of Ci-navigated extension and flexion gap balancing in total knee arthroplasty and analysis of potential predictive variables. *Arch Orthop Trauma Surg*. 2012;132:565–574.
- Heesterbeek PJ, Wymenga AB. Correction of axial and rotational alignment after medial and lateral releases during balanced gap TKA: a clinical study of 54 patients. *Acta Orthop*. 2010;81: 347–353.
- Hernández-Vaquero D, Sandoval-García MA. Hinged total knee arthroplasty in the presence of ligamentous deficiency. *Clin Orthop Relat Res*. 2010;468:1248–1253.
- Insall JN, Dorr LD, Scott RD, Scott WN. Rationale of the Knee Society clinical rating system. *Clin Orthop Relat Res*. 1989;248: 13–14.
- Lachiewicz PF, Soileau ES. Ten-year survival and clinical results of constrained components in primary total knee arthroplasty. *J Arthroplasty*. 2006;21:803–808.
- Laskin RS. Fixed varus deformity. In: Hungerford DS, Krackow KA, Kenna RV, eds. *Total Knee Arthroplasty: A Comprehensive Approach*. Baltimore, MD: Lippincott Williams & Wilkins; 1984:184–185.
- Lombardi AV Jr, Berend KR, Leith JR, Mangino GP, Adams JB. Posterior-stabilized constrained total knee arthroplasty for complex primary cases. *J Bone Joint Surg Am*. 2007;89(suppl 3):90–102.
- Morgan H, Battista V, Leopold SS. Constraint in primary total knee arthroplasty. *J Am Acad Orthop Surg*. 2005;13:515–524.
- Mullaji A, Kanna R, Marawar S, Kohli S, Sharma A. Comparison of limb and component alignment using computer-assisted navigation versus image intensifier-guided conventional total knee arthroplasty: a prospective, randomized, single-surgeon study of 467 knees. *J Arthroplasty*. 2007;22:953–959.
- Mullaji A, Sharma A, Marawar S, Kanna R. Quantification of effect of sequential posteromedial release on flexion and extension gaps: a computer-assisted study in cadaveric knees. *J Arthroplasty*. 2009; 24:795–805.
- Mullaji A, Shetty GM. Computer-assisted total knee arthroplasty for arthritis with extra-articular deformity. *J Arthroplasty*. 2009; 24:1164–1169.
- Mullaji AB, Marawar SV, Mittal V. A comparison of coronal plane axial femoral relationships in Asian patients with varus osteoarthritic knees and healthy knees. *J Arthroplasty*. 2009;24: 861–867.
- Mullaji AB, Padmanabhan V, Jindal G. Total knee arthroplasty for profound varus deformity: technique and radiological results in 173 knees with varus of more than 20 degrees. *J Arthroplasty*. 2005;20:550–561.
- Mullaji AB, Shetty GM, Lingaraju AP, Bhayde S. Which Factors Increase Risk of Malalignment of the Hip-Knee-Ankle Axis in TKA? *Clin Orthop Relat Res*. 2012 August 16. [Epub ahead of print].
- Noble PC, Scuderi GR, Brekke AC, Sikorski A, Benjamin JB, Lonner JH, Chadha P, Daylamani DA, Scott WN, Bourne RB. Development of a new Knee Society scoring system. *Clin Orthop Relat Res*. 2012;470:20–32.
- Parratte S, Pagnano MW. Instability after total knee arthroplasty. *J Bone Joint Surg Am*. 2008;90:184–194.
- Sekiya H, Takatoku K, Takada H, Sasanuma H, Sugimoto N. Postoperative lateral ligamentous laxity diminishes with time after TKA in the varus knee. *Clin Orthop Relat Res*. 2009; 467:1582–1586.
- Shetty GM, Mullaji A, Bhayde S. Computer guided restoration of joint line and femoral offset in cruciate substituting total knee arthroplasty. *Knee*. 2011;19:611–616.
- Skyttä ET, Haapamäki V, Koivikko M, Huhtala H, Remes V. Reliability of the hip-to-ankle radiograph in determining the knee and implant alignment after total knee arthroplasty. *Acta Orthop Belg*. 2011;77:329–335.
- Verdonk PC, Pernin J, Pinaroli A, Ait Si Selmi T, Neyret P. Soft tissue balancing in varus total knee arthroplasty: an algorithmic approach. *Knee Surg Sports Traumatol Arthrosc*. 2009;17:660–666.
- Yau WP, Chiu KY, Tang WM, Ng TP. Coronal bowing of the femur and tibia in Chinese: its incidence and effects on total knee arthroplasty planning. *J Orthop Surg (Hong Kong)*. 2007;15:32–36.