Case Report

Concurrent femoral and tibial osteotomies versus soft tissue balance in total knee arthroplasty: A technical case report

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ABSTRACT

This case report outlines some of the challenges as well as limitations in correction of osteoarthritis of the knee in combination with extra-articular deformities, and provides a novel and straightforward surgical solution in overcoming these challenges. We describe the case of a 37-year-old male who suffered from advanced bilateral tri-compartmental knee arthritis due to untreated bloodstream-sourced osteomyelitis after birth. Radiographs and surgery confirmed extremely severe deformities. We performed two different surgical techniques in order to correct extra-articular deformities (one-stage approach of concurrent tibial and femoral osteotomy and total knee arthroplasty on one side, and soft tissue balancing with “pie-crusting technique” plus total knee arthroplasty on the other side), with description of subsequent results at 36-months follow-up.

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1. Introduction

Total knee arthroplasty (TKA) is a successful procedure for pain relief and functional restoration in patients with advanced osteoarthritis. During the operation, there are many difficulties for the surgeon, due to the deformities of the bone and soft tissue, such as the restoration of the mechanical axis, the orientation of the components and the stability of the knee joint. Stability, through an accurate ligament balancing, is essential for an acceptable clinical outcome and longevity of TKA.^{1,2} Two recent reports, which examined a little under 500 failed TKAs, instability was the cause of nearly 25% of all the total knee revisions performed.^{1,3} To obtain a balanced knee in mediolateral ligamentous structures during TKA, release of contracted tissues and removal of peripheral osteophytes are necessary to correct deformity. However, severe bone defect and ligament insufficiency often occur in severe deformity of the knee joint, and soft tissue release is not an option for the best outcome.⁴ If present, combined extra-articular deformity of the tibia and the femur can present a challenging reconstructive procedure for orthopedic surgery. Alternative methods to the conventional soft tissue release technique, namely pie-crust technique^{5–7} and reduction

osteotomy,^{8,9} have been reported recently. These 2 alternative methods may reduce the possibility of ligament over-release, and obtain optimal ligament balancing and successful long-term stability. Moreover, in these cases, a posterior cruciate-retaining or a posterior cruciate-substituting knee implant might not be adequate, and a varus-valgus constrained design is mandatory to prevent instability and recurrent deformity.¹⁰ Increased constraint may be required in patients with collateral ligament deficiency or major deformities (e.g. severe osteoarthritis, related to trauma, rheumatoid arthritis, neuropathic arthropathy, or sequelae of anterior poliomyelitis).^{11,12} These implants have an acceptable survival rate at intermediate follow-up, but little is known about their performance at long follow-up.^{13–16} There are some drawbacks of constrained design, such as an increased risk of mechanical loosening caused by the transmission of the varus-valgus stress to the bone-cement interface or the presence of polyethylene particle shedding, particularly by tibial post.¹⁵ Furthermore the revision is difficult to perform, because of the potential risk of extensive bone loss. Other complications after use of constrained implants are unclear in clinical practice, as there is a scarcity of clinical studies in literature, especially in young active patients.

We describe a case of a 37 year old male with a past medical history of post-natal bloodstream-sourced osteomyelitis, presenting with bilateral complex deformity of their knees, and report the surgical technical procedure of a one-stage approach of concurrent

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tibial and femoral osteotomy and constrained total knee arthroplasty on the left side, and soft tissue balancing with “pie-crusting technique” and constrained total knee prosthesis on the right side.

2. Case report

In February 2012 we admitted to our Center (First Clinic – Rizzoli Orthopedic Institute, Bologna) a 37-year old caucasian male with a past medical history of untreated bloodstream-sourced osteomyelitis after birth, leading to severe deformities of his hips and his knees. The patient had undergone numerous corrective surgeries, including several knee arthroscopies, corrective osteotomy and autologus osteochondral transplantation. At that time, he reported increased pain which greatly limited his daily functional activities.

Clinically, the patient was able to walk independently without the aid of crutches, though with obvious antalgic lameness, instability and tendency to fall. Deambulation was hampered by attitude in supination of his feet and internal rotation of the tibia.

On examination, the valgus deformity of the left knee was significantly evident (12°) with important instability. The right leg was deformed in varus (17°), combined with posterior tibial subluxation and low mobility of the patella. Significant mediolateral instability with varus-valgus stress test was reported bilaterally. The overlying skin was normal with no signs of infection and no neurovascular deficit. The range of motion was bilaterally compromised: patient was able to bend the left knee up to 60° and the right one up to 70° , after that severe pain and mechanical stoppage limited further flexion.

Pre-operative Knee injury and Osteoarthritis Outcome Score [KOOS] were 19.0 for right knee and 25 for left knee.

The patient was taking on a daily basis etoricoxib and anxiolytic drugs (VAS score reported was 6).

New weight-bearing panoramic view X-rays (Fig. 1) were performed in order to evaluate lower limb alignment (mechanical and anatomical axis), measure the valgus and varus deformity and plan the amount of correction. New CT scan completed pre-operative study.

X-ray images showed an advanced degenerative joint disease of the knees on dysmorphic base, with femoral hypoplasia and tibial and peroneal hypermetria on the left side, and femoral hypermetria with posterior tibial subluxation and reverse tibial slope on the right side (Fig. 2), without significant dysmetria overall lower limbs. Moreover, marked degenerative aspects with severe joint deformity were reported, in particular procurvatum aspect of left femoral shaft, bilateral valgus femoral neck and joint subluxation of the right knee with flattening of the joint profiles and flaring of the same.

We decided to proceed, initially, with a diagnostic arthroscopy of the left knee, performing multiple biopsies for bacterial culture and sensitivity testing, in order to exclude active infectious arthritis. The surgeon reported severe three-compartmental osteoarthritis with multiple grade IV cartilage lesions (according to ICRS classification) of the femoral trochlea, instability of the central pivot and complete fibrosis of the retropatellar area with medial patellar luxation in “patella baja”. Microbiological cultures did not show significant bacterial growth, furthermore all blood values of inflammation were negative: his complete blood count was normal, hemoglobin was 15.8 g/dl, Erythrocyte Sedimentation Rate was 5 mm/1st h (range 0–20) and C-reactive protein was <0.1 mg/dl (range 0–0.50). Therefore we considered the patient as not infected and proceeded with therapeutic protocol of secondary arthritis.

We planned an approach to bilateral knee arthroplasty, consisting: for the left knee in constrained arthroplasty and

Fig. 1. Weight-bearing long leg view X-ray. Valgus deformity of the left knee was estimated 12° ; the right leg was deformed in varus (17°).

concomitant femoral and tibial osteotomies; after 6 months, for the right knee constrained arthroplasty with soft tissue balance.

3. Surgical technique

The first knee prosthesis (left side) was performed in December 2012. Considering severe valgus deformities and great medio-lateral instability, the senior surgeon chose to implant a constrained prosthesis (PFC[®] SIGMA[®] TC3 Knee System, DePuy, Warsaw, IN, USA) after performing tibial and femoral varus osteotomy in order to achieve better correction.

Under combined spinal-epidural anesthesia, with patient in supine position and using a tourniquet, a standard medial parapatellar approach was used to expose the knee. Extensive erosive

Fig. 2. X-ray image showing advanced degenerative joint disease of the knees on a dysmorphic base. A. Anteroposterior view B. Lateral left knee view C. Lateral right knee view.

and fibrous changes were noted, including absolutely no cartilage throughout the joint and fibrous tissue between all the compartments. A tibial tubercle osteotomy was necessary in order to overturn the patella and obtain thereby adequate exposure. In order to correct axial deviation, a femoral and tibial varus osteotomy was concurrently performed. For the tibial osteotomy, a laterally based wedge was cut approximately 2 cm below the joint line and above the tibial tubercle. No fibular osteotomy was performed. The osteotomy was subsequently fixed with intramedullary stem of tibial component of implant. The same procedure was performed for femoral osteotomy: a step-cut varus osteotomy, laterally based, was cut 3 cm above the joint line, after the hardware removal.

After that, our attention was focused on performing knee replacement. Tibia was prepared at first, with a bone cut of 5 mm depth, measured from more affected antero-lateral tibial plateau, correcting also the inverted slope. In preparation of the femoral cut, after reaming the medullary canal, distal resection was

performed setting the valgus angle to 5°. Completed femoral resection, extension and flexion gap was checked for passage of minimum thickness (10 mm) spacer, limb alignment, stability and rectangular shape. Trialling was done, the knee was stable in flexion and extension and patellar tracking was satisfactory by the “no-thumb test”. After irrigating the knee, the osseous surfaces were dried and the final implants were cemented into place. The tibial osteotomy was then fixed with 3 circular cerclage wirings.

Post-operative period was uneventful; active and passive knee motions were recommended the day after surgery. The range of motion was increased gradually according to pain tolerance for the first three weeks. An extension-locked knee brace was advised for the first 30 days. We recommended patient to walk with crutches and to avoid weight bearing on the affected knee for the first six weeks after surgery. Partial weight bearing increasing to complete weight bearing was permitted upon radiographic evidence of healing of the osteotomy site over 6 weeks (Fig. 3).

The right knee, replaced 6 months later, underwent the same implant design (PFC® SIGMA® TC3 Knee System, DePuy, Warsaw, IN, USA), considering great instability in mediolateral stress and severe degeneration in varus.

With the patient under spinal anaesthesia, a midline incision was made over the right patella and a medial parapatellar approach was performed. Also in this case, a tibial tubercle osteotomy was performed in order to overturn patella and obtain thereby adequate exposure. Osteotomies were not required and soft tissue balance was performed through inside-out pie-crusting of the iliotibial band (ITB) and hamstring in order to reduce posterior tibial subluxation, over selective pie-crusting of superficial medial collateral ligament and posteromedial capsule. A standard 19-gauge aspiration needle was used to pierce the tensest fibers by puncturing in a perpendicular or slightly oblique fashion, while the knee was continuously stressed in valgus. It was easy to identify the tense fibers by digital palpation holding the knee under stress. Punctures with alternating stab patterns were made into the tense medial soft tissue from the medial epicondyle to the tibial insertion. If the tightness was observed in extension or flexion only, the punctures were carried out respectively at the anterior fibers or posterior fibers, respectively.

The proximal tibia and distal femur were prepared for knee resurfacing in the same manner as on the right knee: the box cut was performed and the posterior cruciate ligament, posterior capsule, and gastrocnemius were completely released. Next, trial femoral and tibial components were placed, resulting in good medial and lateral stability in flexion. The final implants were cemented into place; the tibial osteotomy was then fixed with circular cerclage wirings (Fig. 4). After skin suture, a compressive bandage was placed.

Fig. 3. Post-operative left knee X-ray view. A. Lateral view B. Anteroposterior view.

Fig. 4. Post-operative right knee X-ray view. A. Lateral view B. Anteroposterior view.

The post-operative protocol was similar: we allow deambulation with partial weight-bearing with crutches for 30 days, with continuous range of motion exercise of the leg; mobilization was commenced from the first day after surgery and it was progressively increased as tolerated.

4. Results and complications

The patient had clinical and radiographic follow-ups at 1, 3, 6, and 12 months after surgery, and every year thereafter, until the maximum follow-up of 48 months (Fig. 5).

Clinical outcome at the last follow-up was assessed on the basis of severity of pain (as assessed on a visual analog scale [VAS]), knee function (as measured with Knee injury and Osteoarthritis Outcome Score [KOOS]) and range of motion; results were compared with baseline values. At 4 years of follow-up patient reported significant reduction of pain (VAS score = 1), a knee range of motion from 0 to 100 on the left side with no extensor lag, stable knee, valgus correction with no subluxation of tibia or flexion deformity at knee but with residual shortening of the leg when compared to the right side (3 cm). The right knee was corrected with good alignment but affected by reduction of ROM (0–60°) for inappropriate compliance with the physiotherapy protocol depending on extra-medical reasons (Fig. 6). Further treatments will be planned. No complications arising from infection were reported.

The patient's Knee injury and Osteoarthritis Outcome Score [KOOS] at 48 months of follow-up, was significantly improved if compared with the baseline level (19.0), although negatively affected by the poor results of the right knee arthroplasty (right knee KOOS score was 29.8 with subtotal Pain score of 53.57% and subtotal Symptoms and Stiffness score of 19.44% of maximum score, left side KOOS score was 43.5 with a subtotal Pain score of 75% and a subtotal Symptoms and Stiffness score of 64.29% of the maximum score).

5. Discussion

While dealing with the challenge of performing a total knee arthroplasty in a patient with post osteomyelitis deformity, the surgeon faces several unique challenges. A wide range of bone and soft tissue deformities put pressure on his ability, impacting the initial success and long term durability of a total knee replacement. There are quite a few case reports pertaining to knee arthroplasty in cases of complex knee deformities, and none of these describe secondary post-osteomyelitis arthritis.^{17–19}

Osteoarticular infections (OAI) are frequent in pediatrics, with an annual incidence in developed countries between 10 and 25 per 100,000 children.²⁰ If not treated, severe bone damages can result in residual complex deformities, and a reconstruction surgery is a challenge for every surgeon. Recent progress in surgery tends to increasingly abandon conservative therapeutic protocol, approving treatments for early arthroplasty, also in young and active patients²¹ taking into account, however, the risk of reactivating infection. Our patient presented a dramatic past medical story and complex bilateral knee deformities. An advanced degenerative joint disease of the knees was present with dysmorphic alteration of femur and tibia, posterior tibial subluxation and reverse tibial slope, due to the shift of all weight-bearing to the anterior compartment, typical of long term deformities of bones as in the case of paralytic genu recurvatum. Severe articular changes upset the physiological anatomy and the stability of his knees.

As reported by Ranawat,²² in severe axis deviation the medial and lateral stabilizing elements are typically not functional, so a constrained implant is often required.^{22,23} Constrained prosthesis is designed to maintain a constant center of rotation throughout the range of motion. This provides uniform ligament tension during the transition from full extension to deep flexion by preserving ligament isometry. This eliminates mid-flexion instability, which is a common concern especially in revision and complex knee surgery. Constrained condylar knee (CCK) prostheses have a number of theoretical disadvantages such as an increased risk of mechanical loosening due to the increased constraint or to the presence of polyethylene particle shedding, particularly by the tibial post.^{24,25} Other theoretical risks are knee malalignment and increased varus/valgus instability in the long-term due to polyethylene creep at the tibial post. The risk of these complications in clinical practice is unclear, as few studies have specifically addressed CCK implants and most of them had less than 10 years of follow-up.^{13,26,27} In a recent meta-analysis of condylar constrained prosthesis, used for complex primary arthroplasties, survival rate at the last follow-up (varying from 5 to 10 years) varied from 89% to 100%, with significant improvement of clinical and functional scores from preoperatively to postoperatively.¹⁴ Cholewinski et al.¹⁵ did not show increased 10-year rates of osteolysis or loosening, with a survival rate after a mean of 11 years follow-up of 88.5%, similar to results published in other studies.¹⁶ However, few studies report the use of constrained prosthesis in young active patients, with follow-up lesser than 24 months.¹⁹ After a thorough review of current literature concerning the topic, this is to our knowledge the first case reports of its kind.

One of the keys to long-term success in primary TKR is stability and this goal can be achieved through correct soft tissue balance. Fascia lata and the ilio-tibial band are the main deforming forces in the flexion and valgus deformity, and the ITB with hamstring contracture contributes to the posterior subluxation of the tibia. The contracted ITB may be released by transverse section above the joint line²⁸ or by sub-periosteal elevation from the Gerdy's tubercle, or modulated, by section of the Kaplan fibres by Z or VY plasty and "pie crusting".²⁹ It is believed that the pie-crust is a reliable technique to correct moderate to severe fixed valgus deformed knees with excellent results and limited

Fig. 5. Clinical images at 36-month follow-up. A. Anteroposterior view. B. Lateral view with maximum right knee flexion (60°) C. Lateral view with maximum flexion of the left knee (100°) D. Lateral view with maximum extension of his knees.

complications,^{29,30} but few studies report this technique of lateral release, justified only in severe valgus deformities that require constrained prosthesis as in the one we have described.^{22,23} However isolated fascia lata release proves sufficient only in small deviations. Biceps femoris, the strongest hamstring, and the lateral head of the gastrocnemius muscle plays an important role in valgus and external rotation. Other methods to deal with the deformity consist of lengthening of vastus lateralis tendon, release of the posterolateral capsule, sub-periosteal release of the femoral attachment of the lateral collateral ligament, dissection of the popliteal muscle and tightening of the medial structures.^{22,31}

The conventional technique for achieving coronal plane stability in the varus deformity is the release of medial soft tissue, including distal attachment of the superficial MCL. Release of hamstring tendons and the posteromedial capsule, sub-periosteal release of the femoral attachment of the medial collateral ligament and dissection of the semimembranosus muscle are other methods described to deal with the deformity.^{32–37} The conventional medial soft tissue release technique runs the risk of medial over-release, which may result in instability and early failure after TKA.^{34,35} To reduce the chance of over-release of the MCL, hematoma formation, and the need for constrained implants, several alternative medial release techniques have been suggested. As an alternative method to the conventional medial release

technique, the pie-crust method has been most commonly reported in recent studies,^{5–7,38,39} with good results, especially regarding extension gap. During the pie-crust procedure, it may be difficult to approach the posterior portion of contracted medial soft tissue including the posterior capsule and posterior oblique ligament. It can be a possible explanation for the limited effect on medial gap change in knee extension by the pie-crust method.

However, when total knee replacements are complicated by extra-articular deformities, soft tissue balance may be not enough and additional procedures on bones are necessary, in order to obtain proper anatomic and mechanical alignment of the limb. Identification of the deformity at the joint line, metaphyses or diaphysis is paramount in determining its effect in extremity alignment. A two-stage correction osteotomy and TKA results in more surgery for the patient and in a long rehabilitation period. Alternatively, this dilemma can be approached with a one-stage approach for full correction of the deformity and alignment at the time of joint arthroplasty. This report presents a patient with a complex deformity treated with a single-stage femoral and tibial osteotomy and knee resurfacing. Although more traditional approaches to this knee reconstruction were considered, we believed that this deformation cannot be corrected through a large articular bones resection. First results of single-stage total knee arthroplasty and extra-articular deformity correction are

Fig. 6. X ray view at 36-month follow-up. A.B.C. Anteroposterior view D. Lateral right knee view E. Lateral left knee view.

promising; however, this technique is still infrequently described in literature. Lonner et al.⁴⁰ reviewed retrospectively results of simultaneous corrective osteotomy and total knee arthroplasty in eleven knees with osteoarthritis and associated extra-articular angular deformity of the femur. According to the classification system of the Knee Society, the mean function score increased from 22 points preoperatively to 81 points at the time of follow-up and the mean knee score increased from 10 points preoperatively to 87 points at the time of follow-up. Ten femoral osteotomy sites (89%) healed; there were no complete radiolucent lines at the prosthetic interfaces, and no total knee arthroplasty was revised. Madelain et al.⁴¹ described good results in 12 patients at 78 months average follow-up, with improvement of functional score and correction of the femoro-tibial mechanical axis (from 161.7° preoperatively to 175.8°). The most extensive retrospective study was published by Veltman⁸ who reviewed twenty-one patients with severe extra-articular deformity who underwent single-stage TKA and deformity-correcting osteotomy, with good results in the

majority of cases. Ten patients were treated with TKA and supracondylar femoral osteotomy and eleven patients were treated with TKA and high tibial osteotomy. Patients were satisfied with the results, with the development of complication (infection) in only two patients, resulting in one arthrodesis and one gastrocnemius transfer for wound closure.

In other papers regarding concomitant reduction osteotomies and soft tissue balance techniques, comparisons of both technique were reported,^{42,43} with success rate up to 90.6% and 67.9% in reduction osteotomy and pie-crust groups, respectively ($P=0.007$), although it is difficult to find a direct comparison between the 2 alternative methods in terms of the desired outcome for the TKA patients. However reduction osteotomy seems more effective in widening the medial extension gap, whereas the pie-crust technique performed better in widening the medial flexion gap. In our report, best results in terms of functionality and pain regression are reported with the concomitant reduction osteotomy plus arthroplasty technique; however it is difficult to have

definitive conclusion only with a patient, also considering that the results are affected also by different patient's compliance to two different physiotherapeutic protocols.

6. Conclusion

This case outlines some of the challenges and limitations in the correction of osteoarthritis of the knee in combination with extra-articular deformities, and provides different strategy protocols in overcoming these challenges. Furthermore, performing two different operations in the same patient to correct severe knee deformation warrants attention, more study are necessary in order to fill this cultural gap. However, both patients and surgeon should be aware of the higher risk of complications and risk of failure when deciding to perform these procedures.

Conflict of interest

None.

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References

- Fehring TK, Odum S, Griffin WL, Mason JB, Nadaud M. Early failures in total knee arthroplasty. *Clin Orthop Relat Res*. 2001;392:315–318.
- Clarke HD, Scuderi GR. Flexion instability in primary total knee replacement. *J Knee Surg*. 2003;16:123–128.
- Sharkey PF, Hozack WJ, Rothman RH, Shastri S, Jacoby SM, Insall Award paper: why are total knee arthroplasties failing today? *Clin Orthop*. 2002;404:7–13.
- Cho WS, Byun SE, Lee SJ, et al. Laxity after complete release of the medial collateral ligament in primary total knee arthroplasty. *Knee Surg Sports Traumatol Arthrosc*. 2015;23(6):1816.
- Bellemans J, Vandenuecker H, Van Lauwe J, et al. A new surgical technique for medial collateral ligament balancing: multiple needle puncturing. *J Arthroplasty*. 2010;25(7):1151.
- Meftah M, Blum YC, Raja D, et al. Correcting fixed varus deformity with flexion contracture during total knee arthroplasty: the inside-out technique: AAOS exhibit selection. *J Bone Joint Surg Am*. 2012;94(10):e66.
- Mihalko WM, Woodard EL, Hebert CT, et al. Biomechanical validation of medial pie-crusting for soft-tissue balancing in knee arthroplasty. *J Arthroplasty*. 2015;30(2):296.
- Veltman ES, van Wensen RJ, Defoort KC, van Hellemond GG, Wymenga AB. Single-stage total knee arthroplasty and osteotomy as treatment of secondary osteoarthritis with severe coronal deviation of joint surface due to extra-articular deformity. *Knee Surg Sports Traumatol Arthrosc*. 2015;(December).
- Mullaji AB, Shetty GM. Correction of varus deformity during TKA with reduction osteotomy. *Clin Orthop Relat Res*. 2014;472(1):126.
- Sculco TP. The role of constraint in total knee arthroplasty. *J Arthroplasty*. 2006;21(4):54–56.
- Massin P, Bonnin M, Paratte S, Vargas R, Piriou P, Deschamps G. Total knee replacement in post-traumatic arthritic knees with limitation of flexion. *Orthop Traumatol Surg Res*. 2011;97:28–33.
- Girard J, Amzallag M, Pasquier G, et al. Total knee arthroplasty in valgus knees: predictive preoperative parameters influencing a constrained design selection. *Orthop Traumatol Surg Res*. 2009;95:260–266.
- Maynard LM, Sauber TJ, Kostopoulos VK, Lavigne GS, Sewecke JJ, Sotereanos NG. Survival of primary condylar-constrained total knee arthroplasty at a minimum of 7 years. *J Arthroplasty*. 2014;29:1197–1201.
- Touzopoulos P, Drosos GI, Ververidis A, Kazakos K. Constrained implants in total knee replacement. *Surg Technol Int*. 2015;26(May):307–316.
- Cholewinski P, Putman S, Vasseur L, et al. Long-term outcomes of primary constrained condylar knee arthroplasty. *Orthop Traumatol Surg Res*. 2015;101(June (4)):449–454.
- Lachiewicz PF, Soileau ES. Ten-year survival and clinical results of constrained components in primary total knee arthroplasty. *J Arthroplasty*. 2006;21:803–808.
- Lahav A, DiMaio FR. Concurrent opening wedge osteotomy and total knee replacement in a patient with posttraumatic arthritis and a varus tibial malunion. *Am J Orthop (Belle Mead NJ)*. 2007;36(August (8)):E121–E123.
- Lal H, Sabharwal VK, Tanwar Y. Total knee replacement in triple deformity with posterior subluxation of the knee joint. *J Clin Orthop Trauma*. 2015;6(June (2)):113–119.
- Kitchen B, Sanchez HB, Wagner RA. Shortening femoral osteotomy with stemmed resurfacing total knee arthroplasty for severe flexion contracture in juvenile rheumatoid arthritis. *J Orthop*. 2014;12(July (2)):118–121.
- Dodwell ER. Osteomyelitis and septic arthritis in children: current concepts. *Curr Opin Pediatr*. 2013;25:58–63.
- Long WJ, Bryce CD, Hollenbeck CS, Benner RW, Scott WN. Total knee replacement in young, active patients: long-term follow-up and functional outcome. *J Bone Joint Surg Am*. 2014;96: e159(1–7).
- Ranawat AS, Ranawat CS, Elkus M, Rasquinha VJ, Rossi R, Babhulkar S. Total knee arthroplasty for severe valgus deformity. *J Bone Joint Surg Am*. 2005;87(Suppl. 1):271–284.
- Krackow KA, Jones MM, Teeny SM, Hungerford DS. Primary total knee arthroplasty in patients with fixed valgus deformity. *Clin Orthop Relat Res*. 1991;273:9–18.
- Marion B, Hutten D, Boyer P, Jeanrot C, Massin P. Medium-term osteolysis with the Wallaby I[®] deep-dished total knee prosthesis. *Orthop Traumatol Surg Res*. 2014;100:403–408.
- Puloski SK, McCalden RW, MacDonald SJ, Rorabeck CH, Bourne RB. Tibial postwear in posterior stabilized total knee arthroplasty. An unrecognized source of polyethylene debris. *J Bone Joint Surg Am*. 2001;83:390–397.
- Lachiewicz PF, Soileau ES. Results of a second-generation constrained condylar prosthesis in primary total knee arthroplasty. *J Arthroplasty*. 2001;26:1228–1231.
- Anderson JA, Baldini A, MacDonald JH, Pellicci PM, Sculco TP. Primary constrained condylar knee arthroplasty without stem extensions for the valgus knee. *Clin Orthop Relat Res*. 2006;442:199–203.
- Zenz P, Huber M, Obenaus CH, Schwagerl W. Lengthening of the iliotibial band by femoral detachment and multiple puncture. A cadaver study. *Arch Orthop Trauma Surg*. 2002;122:429–431.
- Aglietti P, Lup D, Cuomo P, Baldini A, De Luca L. Total knee arthroplasty using a pie-crusting technique for valgus deformity. *Clin Orthop Relat Res*. 2007;464(November) 73e77.
- Clarke HD, Fuchs R, Scuderi GR, Scott WN, Insall JN. Clinical results in valgus total knee arthroplasty with the pie crust technique of lateral soft tissue releases. *J Arthroplasty*. 2005;20:1010–1014.
- Krackow KA, Holtgrewe JL. Experience with a new technique for managing severely overcorrected valgus high tibial osteotomy at total knee arthroplasty. *Clin Orthop Relat Res*. 1990;258:213–224.
- Seo JG, Moon YW, Jo BC, et al. Soft tissue balancing of varus arthritic knee in minimally invasive surgery total knee arthroplasty: comparison between posterior oblique ligament release and superficial MCL release. *Knee Surg Relat Res*. 2013;25(2):60.
- Koh HS, In Y. Semimembranosus release as the second step of soft tissue balancing in varus total knee arthroplasty. *J Arthroplasty*. 2013;28(2):273.
- Krackow KA, Mihalko WM. The effect of medial release on flexion and extension gaps in cadaveric knees: implications for soft-tissue balancing in total knee arthroplasty. *Am J Knee Surg*. 1999;12(4):222.
- Whiteside LA, Saeki K, Mihalko WM. Functional medial ligament balancing in total knee arthroplasty. *Clin Orthop Relat Res*. 2000;380:45.
- Hunt NC, Ghosh KM, Athwal KK, et al. Lack of evidence to support present medial release methods in total knee arthroplasty. *Knee Surg Sports Traumatol Arthrosc*. 2014;22(12):3100.
- Mullaji A, Sharma A, Marawar S, et al. Quantification of effect of sequential posteromedial release on flexion and extension gaps: a computer-assisted study in cadaveric knees. *J Arthroplasty*. 2009;24(5):795.
- Verdonk PC, Pernin J, Pinaroli A, et al. Soft tissue balancing in varus total knee arthroplasty: an algorithmic approach. *Knee Surg Sports Traumatol Arthrosc*. 2009;17(6):660.
- Meneghini RM, Daluga AT, Sturgis LA, et al. Is the pie-crusting technique safe for MCL release in varus deformity correction in total knee arthroplasty? *J Arthroplasty*. 2013;28(8):1306.
- Lonner JH, Siliski JM, Lotke PA. Simultaneous femoral osteotomy and total knee arthroplasty for treatment of osteoarthritis associated with severe extra-articular deformity. *J Bone Joint Surg Am*. 2000;82:342–348.
- Madelaine A, Villa V, Yela C, et al. Results and complications of single-stage total knee arthroplasty and high tibial osteotomy. *Int Orthop*. 2014;38:2091–2098.
- Ahn JH, Back YW. Comparative study of two techniques for ligament balancing in total knee arthroplasty for severe varus knee: medial soft tissue release vs. bony resection of proximal medial tibia. *Knee Surg Relat Res*. 2013;25(1):13.
- Ahn JH, Yang TY, Lee JY. Reduction osteotomy vs pie-crust technique as possible alternatives for medial release in total knee arthroplasty and compared in a prospective randomized controlled trial. *J Arthroplasty*. 2016;31(7):1470–1475.