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M. BONNIN, S. LUSTIG, A. PINAROLI,
E. SERVIEN, J-M. FAYARD, R. BADET,
G. DEMEY, T. AÏT SI SELMI, F. TROUILLET

Avec la collaboration de :

T. Aït Si Selmi, F. Al-Shakfa, R. Badet, R. Bastos-Filho, J. Bellemans, D. Beverland, M. Blaysat, M. Bonnin, P. Chambat, K.J. Cho, J. Chouteau, M. Coolican, M. Corbella, O. Courage, C. Debette, D. Dejour, A. De Kok, G. Demey, G. Deschamps, E. Doran, P. Erasmus, J.-M. Fayard, W. Fitz, A. Gregori, M. Grimaldi, V. Guinet, S. Gunst, J. Hill, K. Iguer, N. Jan, A. Kinninmonth, A. Krayan, V. Krenn, F. Lavoie, F. Leitner, B. Le Negaret, L. Lidgren, T. Lording, S. Lustig, D. McDonald , A. Madelaine, R.A. Magnussen, L. Malekpour, M. Marullo, J.H. Müller, C. Murphy, P. Neyret, P.G. Ntagiopoulos, S. O'Brien, J. Oosterbosch, S. Oussedik, R. Pagoti, D. Parker, J.-R. Pécora, F. Picard, S. Piedade, O. Reynaud, O. Robertsson, J. Robin, S. Romagnoli, M. Saffarini, D. Saragaglia, C. Scholes, E. Servien, D. Shepherd, M. Sundberg, P. Thomas, M. Thomsen, S. Tomes, J. Truijen, C. Van der Straten, T. Van Hoof, M. Verstraete, J. Victor, V. Villa, A. W-Dahl, T. Zakaria

SAURAMPS MEDICAL

11, boulevard Henri IV - 34000 Montpellier
E.mail : sauramps.medical@wanadoo.fr

LISTE DES AUTEURS

T. AÏT SI SELMI : Centre Orthopédique Santy – 24, av. Paul Santy - 69008 Lyon, France

F. AL-SHAKFA : Centre Hospitalier de l'Université de Montréal (CHUM) - Montréal, Québec, Canada

R. BADET : Pôle ostéo-articulaire santé et sport - 60, av. du Médipôle - 38300 Bourgoin Jallieu, France

R. BASTOS-FILHO : Hospital Federal dos Servidores do Estado, Rio de Janeiro, RJ, Brasil

J. BELLEMANS : Ziekenhuis Oost-Limburg - Schiepse Bos 6 - 8900 Genk - Belgium

D. BEVERLAND : Musgrave Park Hospital Belfast

M. BLAYSAT : Department of Orthopaedic Surgery and Sport Traumatology. Grenoble South Teaching Hospital. Echirolles, France

M. BONNIN : Centre Orthopédique Santy – 24, av. Paul Santy - 69008 Lyon, France – UZ Gent. De Pintelaan, 185, Gent, Belgium

P. CHAMBAT : Centre Orthopédique Paul Santy - 24, avenue Paul Santy - 69008 Lyon, France

K.J. CHO : Department of Orthopaedic surgery and Biomedical Engineering Research Group, Department of Mechanical and Mechatronic Engineering, University of Stellenbosch, South Africa

J. CHOUTEAU : Cabinet de Chirurgie Orthopédique et de Chirurgie du Sport - Allée de la Mandallaz, Immeuble Le Périclès - Montée B - 74370 Metz-Tessy — Clinique Argonay - 685, route de Menthonnex - 74370 Argonay, France

M. COOLICAN : Groupement Hospitalier Lyon Nord - 103, grande rue de la Croix-Rousse - Pav R - 69317 Lyon Cedex 04, France

M. CORBELLA : Centro di Chirurgia Protesica, IRCCS Istituto Ortopedico Galeazzi, Milano

O. COURAGE : Hôpital privé de l'Estuaire - 505, rue Irène Joliot-Curie - BP 90011 - 76620 Le Havre, France

C. DEBETTE : Groupement Hospitalier Lyon Nord - 103, grande rue de la Croix-Rousse - Pav R - 69317 Lyon Cedex 04, France

D. DEJOUR : Lyon-Ortho-Clinic ; Clinique de la Sauvegarde - 8, avenue Ben Gourion - 69009 Lyon, France

A. DE KOK : UZ Gent. De Pintelaan, 185, Gent, Belgium

G. DEMEY : Lyon-Ortho-Clinic ; Clinique de la Sauvegarde - 8, avenue Ben Gourion - 69009 Lyon, France

G. DESCHAMPS : Centre Orthopédique - 2, rue du Pressoir - 71640 Dracy-le-Fort, France

E. DORAN : Musgrave Park Hospital Belfast

P.J. ERASMUS : G3 Stellenbosch Medi Clinic - Die Boord - Stellenbosch 7600 - South Africa

J.M. FAYARD : Centre Orthopédique Paul Santy - 24, avenue Paul Santy - 69008 Lyon, France

W. FITZ : Brigham and Women's and Brigham's/Faulkner Hospital, Boston MA

A. GREGORI : Orthopaedic Department Golden Jubilee National Hospital - Agamemnon Street. G814DY - Bioengineering Department Strathclyde University Glasgow UK

M. GRIMALDI : Department of Orthopaedic Surgery and Sport Traumatology. Grenoble South Teaching Hospital. Echirolles, France

V. GUINET : Hôpital privé de l'Estuaire - 505, rue Irène Joliot-Curie - BP 90011 - 76620 Le Havre, France

S. GUNST : Department of Orthopaedic Surgery - Sports Health and Performance Institute - The Ohio State University - Columbus, OH, USA

J. HILL : Musgrave Park Hospital Belfast

K. IGUER : Centre Hospitalier de l'Université de Montréal (CHUM) - Montréal, Québec, Canada

N. JAN : Centre Orthopédique Paul Santy - 24, avenue Paul Santy - 69008 Lyon, France

A. KINNINMONTH : Orthopaedic Department Golden Jubilee National Hospital - Agamemnon Street G814DY

A. KRAYAN : Department of Orthopaedic Surgery and Sport Traumatology. Grenoble South Teaching Hospital. Echirolles, France

V. KRENN : MVZ-Zentrum für Histologie, Zytologie und Molekulare Diagnostik, Trier

F. LAVOIE : Centre Hospitalier de l'Université de Montréal (CHUM) - Montréal, Québec, Canada

F. LEITNER : Orthopaedic Department Golden Jubilee National Hospital - Agamemnon Street. G814DY - Bioengineering Department Strathclyde University Glasgow UK

B. LE NEGARET, MENG : Department of Research & Development, Tornier SA, Rue Lavoisier - 38330 Montbonnot, France

L. LIDGREN : The Swedish Knee Arthroplasty Register

T. LORDING : Groupement Hospitalier Lyon Nord - 103, grande rue de la Croix-Rousse - Pav R - 69317 Lyon Cedex 04 — Frankston Hospital, Hastings Rd, Frankston VIC 3199, Australia

S. LUSTIG : Groupement Hospitalier Lyon Nord - 103, grande rue de la Croix-Rousse - Pav R - 69317 Lyon Cedex 04, France

D. McDONALD : Orthopaedic Department Golden Jubilee National Hospital - Agamemnon Street G814DY

A. MADELAINE : Service de chirurgie orthopédique, centre Albert Trillat, Université Claude Bernard, Lyon 1 - Hôpital de la Croix-rousse, Hospices civils de Lyon, 103 grande rue de la Croix-rousse - 69004 Lyon, France

R.A. MAGNUSSEN : Department of Orthopaedic Surgery - Sports Health and Performance Institute - The Ohio State University - Columbus, OH, USA

L. MALEKPOUR : Hôpital privé de l'estuaire - 505, rue Irène Joliot-Curie - BP 90011 - 76620 Le Havre, France

M. MARULLO : Centro di Chirurgia Protesica, IRCCS Istituto Ortopedico Galeazzi, Milano

J.H. MÜLLER : Biomedical Engineering Research Group, Department of Mechanical and Mechatronic Engineering, University of Stellenbosch, South Africa

C. MURPHY : Centre Orthopédique Paul Santy – 24, av. P. Santy - 69008 Lyon, France

P. NEYRET : Groupement Hospitalier Lyon Nord - 103, grande rue de la Croix-Rousse - Pav R - 69317 Lyon Cedex 04, France

P.G. NTAGIOPOULOS : Lyon-Ortho-Clinic ; Clinique de la Sauvegarde - 8, avenue Ben Gourion - 69009 Lyon, France

S. O'BRIEN : Musgrave Park Hospital Belfast

J. OOSTERBOSCH : Ziekenhuis Oost-Limburg - Schiepse Bos 6 - 8900 Genk, Belgium

S. OUSSEDIK : Groupement Hospitalier Lyon Nord - 103, grande rue de la Croix-Rousse - Pav R - 69317 Lyon Cedex 04, France

R. PAGOTI : Musgrave Park Hospital Belfast

D. PARKER : Groupement Hospitalier Lyon Nord - 103, grande rue de la Croix-Rousse - Pav R - 69317 Lyon Cedex 04, France

J.-R. PÉCORA : Knee Group - Hospital das Clínicas - Faculdade de Medicina - Universidade de São Paulo - USP Sao Paulo - Brazil

F. PICARD : Orthopaedic Department Golden Jubilee National Hospital - Agamemnon Street. G814DY - Bioengineering Department Strathclyde University Glasgow UK

S. PIEDADE : Professeur à la Faculté des Sciences Médicales de l'Université de Campinas – FCM/UNICAMP – Campinas/Brésil – Chef du Département d´Orthopédie et de Traumatologie – Coordonnateur du Groupe de Médecine du Sport - FCM/UNICAMP

O. REYNAUD : Groupement Hospitalier Lyon Nord - 103, grande rue de la Croix-Rousse - Pav R - 69317 Lyon Cedex 04, France

O. ROBERTSSON : The Swedish Knee Arthroplasty Register

J. ROBIN : Groupement Hospitalier Lyon Nord - 103, grande rue de la Croix-Rousse - Pav R - 69317 Lyon Cedex 04, France

S. ROMAGNOLI : Centro di Chirurgia Protesica, IRCCS Istituto Ortopedico Galeazzi, Milano

M. SAFFARINI, MENG : Accelerate Innovation Management SA - 1, rue de la Navigation - 1201 Geneva, Switzerland

D. SARAGAGLIA : Department of Orthopaedic Surgery and Sport Traumatology. Grenoble South Teaching Hospital. Echirolles, France

C. SCHOLES : Groupement Hospitalier Lyon Nord - 103, grande rue de la Croix-Rousse - Pav R - 69317 Lyon Cedex 04, France

E. SERVIEN : Groupement Hospitalier Lyon Nord - 103, grande rue de la Croix-Rousse - Pav R - 69317 Lyon Cedex 04, France

D. SHEPHERD : Western health, Melbourne, Victoria, Australia

M. SUNDBERG : The Swedish Knee Arthroplasty Register

P. THOMAS : Klinik und Poliklinik für Dermatologie und Allergologie der LMU, München

M. THOMSEN : Mittelbaden Clinics Baden-Baden, Trauma and Orthopaedic Surgery Units – Baden-Baden Balg and Baden-Baden Annaberg, Lilienmattstrasse 5, 76530 Baden-Baden, Germany

S. TOMES : Chef de Clinique Assistant des Hôpitaux - Chirurgie Orthopédique et Traumatologique - CHU Dijon - 21000 Dijon, France

J. TRUIJEN : Ziekenhuis Oost-Limburg - Schiepse Bos 6 - 8900 Genk - Belgium

C. VAN DER STRATEN : UZ Gent. De Pintelaan, 185, Gent, Belgium

T. VAN HOOF : UZ Gent. De Pintelaan, 185, Gent, Belgium

M. VERSTRAETE : UZ Gent. De Pintelaan, 185, Gent, Belgium

J. VICTOR : Dept. of Orthopaedic Surgery and Traumatology, Ghent University Hospital, Ghent University, De Pintelaan 185, 9000 Gent, Belgium

V. VILLA : Groupement Hospitalier Lyon Nord - 103, grande rue de la Croix-Rousse - Pav R - 69317 Lyon Cedex 04, France

A. W-DAHL : Swedish Knee Arthroplasty Register - Dept. of Orthopedics - Skåne University Hospital, Lund - 221 85 Lund, Sweden

T. ZAKARIA : Groupement Hospitalier Lyon Nord - 103, grande rue de la Croix-Rousse - Pav R - 69317 Lyon Cedex 04, France

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PATIENT SPECIFIC INSTRUMENTS IN TOTAL KNEE REPLACEMENT. EXPERIENCE AND LIMITS.

A PROSPECTIVE STUDY AT 3 POST OPERATIVE YEAR

J. CHOUTEAU

INTRODUCTION

Computer assisted surgery (CAS) is an accurate and reliable technique for the placement of femoral and tibial components in total knee arthroplasty (TKA) [1]. However, CAS needs extra operative time, and increases costs because of requiring buying expensive workstation in the operating room. Patient specific instruments (PSI) have been developed to be as accurate as CAS without increasing operating time and without requiring expensive costs. We report results of a prospective and continuous series of our first 40 cases of TKA implanted by means of PSI. The average follow-up was 3 year. We tried to define what the lacks of this technique were and what could be done in the future to improve it.

MATERIALS AND METHODS

We conducted a prospective study on the first 40 cases operated on by means of PSI.

No patient selection was applied. Every patient underwent a pre operative MRI to build the PSI guides (fig. 1). These guides were manufactured after manual segmentation of MRI in order to define anatomical points (fig. 2).

All the patients were clinically followed at 2 month, 6 month, 1 year and 3 post operative year, respectively. Maximal flexion assessment was performed on weight bearing radiographs (lateral view). Frontal alignment was measured on full-leg standing X-rays.

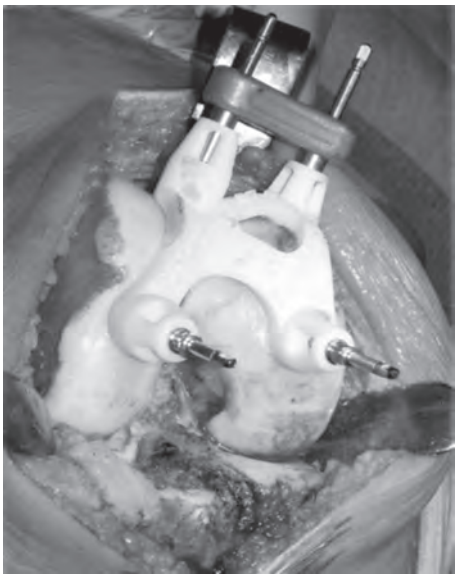

Fig. 1: Femoral Guide. Per operative view.

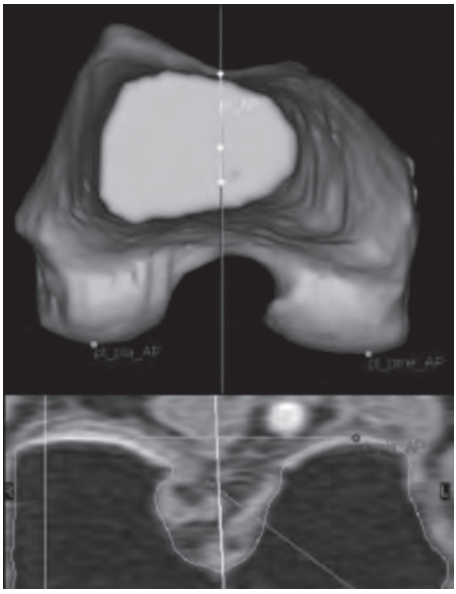

Fig. 2: Example of manual segmentation of MRI: femoral posterior points.

RESULTS

At pre operative time, 30 patients had varus knee (mean 173°; range 163°-179) and 10 patients had valgus knee (mean 188°; range 181°-191°). The average pre operative range of motion (ROM) was 103° (range 70°-130°). The average surgical time was 47min (range 38min-65min) for cementless TKA, and 62min (range 44min-90min) for cemented TKA. 13% of the patients had patellar resurfacing only for severe patello femoral osteoarthritis. The average blood loss was 420ml (range 320ml-920ml). The average post operative frontal alignment was 180°±3° in 96% of the cases. We had one early tibial plateau loosening (cementless implant), revised at 8 post operative month with simple follow-up. One patient fall down in the stairs and had a tibial fracture with revision of the tibial component.

At 2 post operative month, the mean ROM was 119° (73% of the patients > 115°). 2/3 of the patients walked without support. 1/3 of the patients used one crutch when walking outside.

At 6 post operative month, the mean ROM was 126° (fig. 3) (96% of the patients > 120°). None of the patients used crutches. 92% were very satisfied of their operation.

Clinical results at one year and 3 year were similar to 6 month. At the longest follow-up no patellar maltracking was noticed on the skyline views whatever the preoperative position of the patella was (fig. 4).

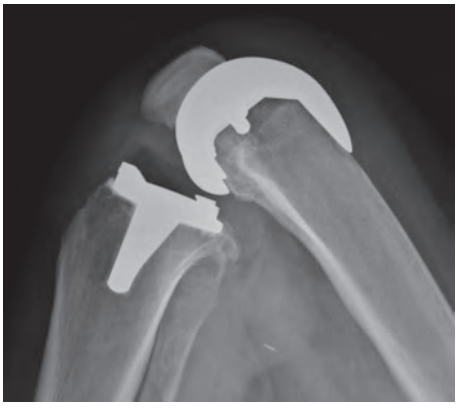

Fig. 3: Maximal flexion at 6 month post op.

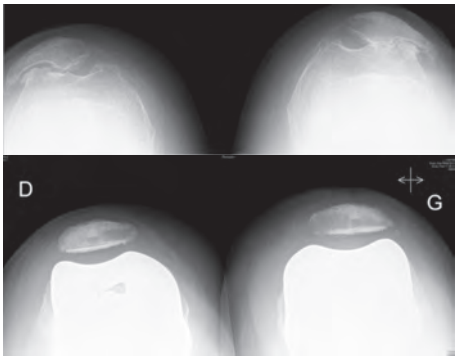

Fig. 4: No patellar maltracking observed with PSI even in sever Patello femoral Joint Osteoarthritis.

DISCUSSION

We found in our series encouraging results similar to those reported in CAS.

However PSI, because of manual segmentation of the MRI, can show variation in the clinical results and in post op frontal alignment because of non appropriate fitting of the guides when placing on the femoral or tibial bone [2].

In several series, the use of PSI did not reduce blood loss, but in these series the tourniquet was used and we have no information about how the hemostasis was conducted [3].

CONCLUSION

In our series, the PSI were reliable and reproducible. However, this technique still requires a manual step for MRI segmentation and to define anatomical points. These drawbacks could introduce a bias in the accuracy of the segmentation, and so, in the guides manufacturing.

Nevertheless, the results of this new technique are encouraging. The PSI technique still remains submit to variability, and won't be improved until all the procedure is computerized.

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PSI AND LIGAMENT BALANCING IN TKA

J. ROBIN, T. ZAKARIA, P. NEYRET

The goals of total knee arthroplasty (TKA) are to implant a balanced, stable knee prosthesis, which alleviates arthritic pain and gains range of motion and function. Obtaining an optimal result in TKA is a complex task and consists of a series of surgical decisions, which usually follows a set algorithm. With recent advances in material technology, poor outcomes from TKA usually do not relate to wear of the polyethylene spacer, but rather due to inaccurate implantation of the prosthesis and inattention to the soft-tissue envelope. This can present with pain, instability or poor range of motion or a combination of all of these symptoms. Obtaining a TKA that is well balanced is a key factor in obtaining an optimal result.

There are many philosophies and techniques that can be used to obtain a balanced TKA. Ultimately the technique used must be accurate, reliable, reproducible, and reduce the potential for systematic error as much as possible.

Implantation of a TKA is an equation with numerous unknown factors, however all of these unknown factors are linked. And as all TKA techniques rely on a series of dependent and linked steps, small errors, especially if they occur early in the procedure often lead to a magnified problem in the final outcome.

In order to obtain a balanced TKA there is a series of bone cuts and soft-tissue releases that should lead to similar spaces or gaps between the tibia and femur in flexion and extension. Bone cuts are determined by their orientation and level. The orientation of the bone resection occurs in two planes and three directions. The level of the bone cut refers to its height or its depth.

The tibial bone resection influences the size of the flexion and extension gap evenly, however it does not allow for correction of flexion and extension gap balancing. The distal femoral bone cut and the posterior femoral bone cut are intimately linked to obtain even gaps. The former leads to the extension gap and the latter leads to the flexion gap and rotation of the implant. They should both be the same in order to obtain a balanced TKA.

The standard classical techniques for balancing in TKA include a measured bony resection with ligament balancing and a gap balancing technique using the soft-tissue tension to determine femoral bone cuts. The former relies heavily on the orientation of the bone cut in association with soft-tissue releases, whereas the latter relies on the level of the bone cut being equal in flexion and extension to provide

equal gaps. All techniques also employ either dependent or independent bony resections. More recent technology has aimed to improve accuracy of TKA by using computer navigation and patient specific instrumentation (PSI).

With a classical technique of dependent bony cuts, the tibia is cut first with the femoral cuts being linked to the tibial cut. This allows for a balanced bony resection of the posterior femur to obtain the flexion gap (and rotation) and the distal femur to obtain the extension gap. The extension gap can be adjusted to the flexion gap or vice versa. With independent cuts, the distal femur, the posterior femur and the tibia are all cut independently and the soft-tissues are balanced to further equalize the flexion and extension gap.

There are benefits and down-sides to all of these techniques, however, a poignant fact is that if the majority of TKA balancing is done early in the procedure, this leaves less to chance and reduces difficulties in balancing the soft-tissues after all bony cuts have been performed. This gives greater control to the surgeon and reduces the possibility of having to perform large releases late in the procedure or to have to use a larger polyethylene spacer than initially anticipated. Minimalizing the uncertainty of TKA balancing during the procedure is the key.

This concept can be explained utilizing the different balancing techniques of measured resection compared to the gap balancing technique.

When the measured resection technique is performed either using a classical instrumented technique, via computer navigation, or PSI, **three independent bone cuts** are made based on a measured resection amount afforded by the jigs or computer simulated plan. Soft-tissue balancing is then performed to allow equalization of the flexion and extension gaps prior to trialing and implantation of the components. The flexion and extension gaps can be checked at the appropriate stages during the procedure, however, there is no other way of controlling the balance of the gaps prior to all bony resections being made. Minor gap balancing alterations may be achieved with soft-tissue releases, however, this method leaves very limited opportunity to correct for any major balancing issues should they occur prior to prosthesis implantation.

Alternatively, when the gap balancing method is used, irrespective of whether the flexion or extension gap is produced first, **two bone cuts** are made followed by ligament balancing and a linked or **dependan**t third bone cut to match the first gap. This allows for ligament balancing earlier in the procedure, prior to establishing both the flexion and extension spaces. Linking the femoral bone cuts after the first gap is created allows earlier appreciation of the soft-tissue restraints and reduces the educated estimation that would otherwise be required to balance the gaps afterwards. This gap balancing technique can be performed using classical instrumented method or with a computer-navigated version, which can simulate the balanced gaps.

Computer navigation may be utilized to perform gap balancing in a third way. This third technique uses only **one bone cut** prior to simulated gap balancing. After standard tibial bone resection, navigation is used to simulate the flexion and extension gaps prior to making any femoral bone cuts. The soft-tissues can be balanced in flexion to obtain the simulated flexion gap, and then in extension for the extension gap. Once the soft-tissues have been balanced and the flexion and extension gaps equalized on the computer navigation, the definitive posterior femoral and distal femoral bone cuts can be executed according to the planned simulation. This technique gives the surgeon greater control on balancing the flexion and extension gaps. After the simulated gaps have been planned and carried out with the prior ligament balancing as necessary there should be little need to perform further balancing later in the procedure. This theory is summarized in Figures 1 and 2.

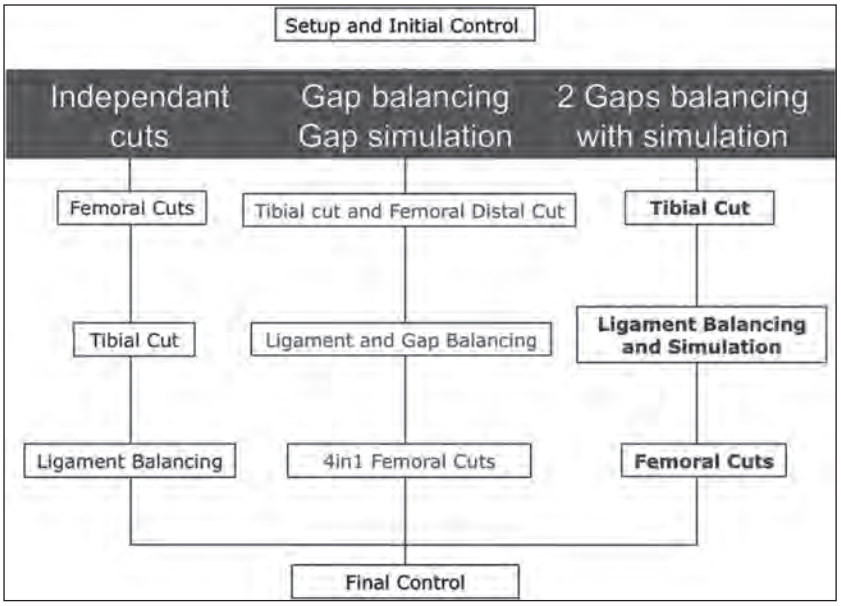

Fig. 1: Three methods of gap balancing during TKA.

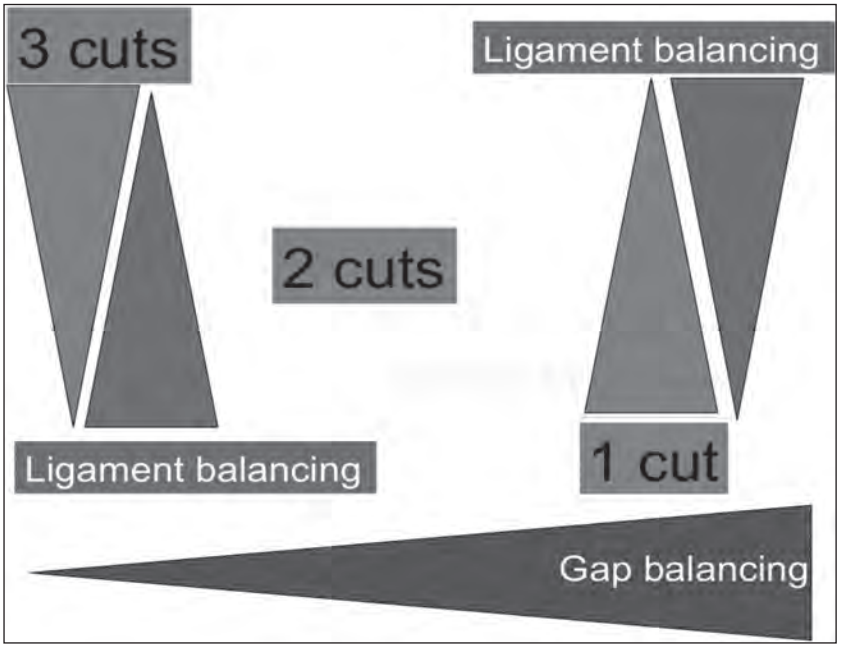

Fig. 2: Schematic illustration, summarizing the different balancing techniques in TKA.

PSI is the most recent advance in TKA technology. It utilizes various imaging modalities to produce cutting blocks matched specifically to the patient's knee anatomy. In theory, this is a very accurate technique that should be reliable and reproducible. The advantages of PSI include the production of an available plan for the surgeon to check prior to surgery, the avoidance of instrumenting the intramedullary canal which can be particularly useful with large extra-articular deformities and reducing the necessary operating inventory and theoretically reducing instrument processing costs.

Many different designs of PSI are currently available for use, and each have their unique method of producing their blocks. Despite the theoretical accuracy of these blocks, the majority of these companies rely on a measured resection technique with three independent cuts followed by ligament balancing. PSI therefore theoretically produces accurate *orientation* of bony cuts, however does not determine the *level of* the cuts needed for gap balancing.

Few companies, however, have been able to combine the accuracy of PSI with a gap balancing technique. This may ultimately provide the surgeon with the greatest accuracy and control over TKA balancing.

In one such technique, the PSI tibial cutting block is used to cut the tibia first. Following this, a patient-specific distal femoral cutting block is used. This block is unique as it is created with an in-built spacer. This block and spacer device occupies the predetermined depth of tibial bone cut. This technique allows the surgeon to verify ligament balancing in extension prior to making any femoral bone cuts. Ligament balancing can be checked directly by coronal plane movement of the knee in extension with the cutting block in situ. This also provides the surgeon with an on-table, real-time assessment of coronal and sagittal plane alignment in extension.

If there is unexpected extension gap imbalance, the surgeon can deal with this prior to making any further bone cuts. There may be need for limited ligament release if the gap is asymmetrically tight. If the knee is symmetrically loose, spacers can be used in order to distalize the femoral cut. If the knee is symmetrically tight, the distal femur may need to be re-cut later. The distal femoral cut created by the block is parallel to the distal femur and the tibial cut, providing a rectangular extension gap.

The flexion gap is then balanced by using the classical instrumentation for cutting the posterior femur. This allows for a reliable, balanced flexion gap to be created whilst simultaneously setting the correct amount of rotation.

In summary, there are three ways of obtaining equal gap balancing during TKA. A technique using three independent bone cuts may give the surgeon least control over balancing a TKA. The technique of having two bone cuts and soft-tissue balancing would appear to give greater control to the surgeon. The greatest control over gap balancing, however, may be from a third method where the tibial bone cut is made first and gap balancing is simulated with navigation. The use of PSI in conjunction with ligament balancing may provide great control, accuracy and reliability in balancing a TKA.

ACCURACY OF PSI: CONTROL WITH NAVIGATION

S. LUSTIG, C. SCHOLES, S. OUSSEDIK, M. COOLICAN, D. PARKER

INTRODUCTION

Accurate position of bone cuts and final alignment is a key factor for the success of total knee arthroplasty (TKA). As a seducing alternative to standard procedure and navigation, Patient Specific Instrumentation has been introduced recently as a means of making accurate bone cuts through custom cutting blocks constructed based on pre-operative 3D imaging.

Even if there may be potential causes of error such as the acquisition of the 3D image, the interpretation of the 3D image by the surgeon or the application of the jigs to the bone, there remains a lack of information regarding the accuracy of patient specific cutting blocks. Therefore, the purpose of this investigation was to evaluate the accuracy and between-patient reliability of bone cuts and the resultant alignment produced by one type of Patient Specific Instrumentation (the Smith and Nephew VISIONAIRE patient-specific cutting block system). Our hypothesis was that the bone cuts induced by the cutting blocks were accurate to within ±3° or ±2mm of the pre-operative plan in each plane.

MATERIAL AND METHODS

The patient specific cutting blocks (PSCB) used in the study were performed with the VISIONAIRE system from Smith and Nephew. A preoperative MRI and a long leg X-ray of the involved lower limb were performed and the data sent to Smith and Nephew. The images were then processed and 3-dimensional models of the tibia and femur digitally constructed. The bone models and digital templates of the prosthesis were uploaded onto a proprietary software planner. Following surgeon approval of the surgical template and alignment of components in multiple planes, rapid-prototyping computer-assisted design and computer-assisted manufacturing technology were used to create the PSCB jigs. TKA was undertaken according to the surgeon's standard technique.

The operated limb was prepared and isolation drapes applied. Intraoperative alignment data were collected using the Stryker Precision navigation system (Stryker Corporation, Kalamazoo, Michigan) as previously described [1]. This system allowed for the assessment of cutting block positioning before the bone cuts.

The hip was taken through a range of motion and a digital hip centre generated by the software package. A midline knee incision was then performed, prior to a medial parapatellar arthrotomy. The medial collateral ligament was elevated from the tibia sufficient to gain access to the joint. Registration of the epicondyles, femoral centre, AP axis and femoral condyles was then undertaken with the navigation system, followed by registration of tibial landmarks and malleoli. The lateral epicondyle was defined as the most lateral prominence of the lateral femoral condyle, whilst the medial epicondyle was defined by the medial sulcus of the medial epicondyle. The navigation software then generated the surgical trans-epicondylar axis, a line connecting the 2 epicondyles.

The PSCB was used in accordance with the manufacturer's instructions, with careful positioning over the articular surfaces. The accuracy with which the PSCB conformed to the articular surface was checked by an observer from Smith and Nephew, ensuring the PSCB was used in the recommended fashion. Drill holes and pins in the tibial and femoral periarticular bone were placed through the respective PSCB to determine the orientation of the standard cutting guides, which were recorded with the navigation system (fig. 1) [2]. The parameters assessed intraoperatively included the PSCB alignment and depth for both the femoral (coronal, sagittal, rotational) and tibial cuts. In addition, agreement between the planned sizing for the tibial and femoral components and the sizing determined intraoperatively was recorded (Table 1).

The PSCB-defined bone cuts were only used if the intra-operative measurements confirmed acceptable alignment, which was defined as within ±2° or ±1mm of the pre-operative plan in each plane. If this was not achieved, the PSCB was removed and the procedure was performed with the navigation system in a standard manner.

Table 1: Parameters assessed intraoperatively.

General	Femoral PSCB	Tibial PSCB
Fit	Sizing	Sizing
Conformity	Coronal alignment	Coronal alignment
Limb alignment	Sagittal alignment	Sagittal alignment
	Rotation	Cut depth
	Cut depth	

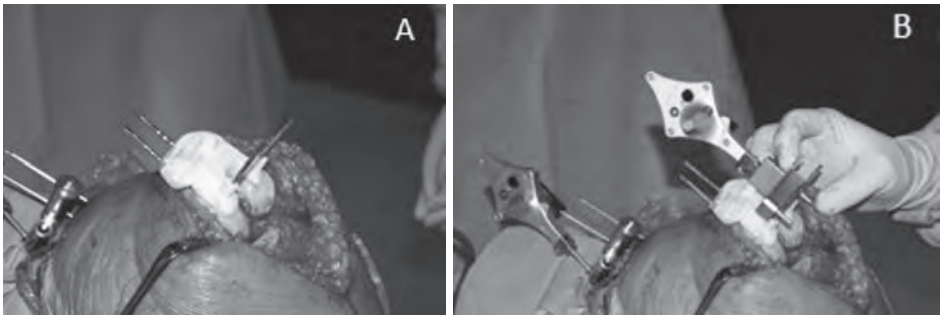

Fig. 1 : Intraoperative view of PSCB positioning for the femur (A) and assessment of alignment with the navigation system (B).

The pre-operative plan and intra-operative measurements were compared with respect to femoral (coronal, sagittal and rotation) and tibial (coronal and slope) alignment. The process was repeated for cut depths on the femur (distal medial and distal lateral) and tibia (medial and lateral plateaus). Normality of the data was assessed using a Ryan–Joiner test prior to further analysis. Variables that failed the test were adjusted by removing outliers (≤2) until the distribution returned to normality. Descriptive statistics (mean, standard deviation and range) were calculated for each variable. One-sample t-tests were applied to determine if the mean difference between the planned and intra-operative measurements differed significantly from zero. The proportion of intra-operative measurements within ±3° or ±2° of the plan was also determined. Similar proportions were calculated for cut depths with ±2mm and ±1mm thresholds. Finally, the predicted range of values for a single future measurement, the prediction interval, was calculated for each variable. The prediction interval indicates the most likely range of values within which the difference between the plan and the intraoperative measurement will fall for the next future patient and provides an indication of the between-patient reliability of the PSCB process. Alpha and confidence interval were set *a-priori* at 5% and 95% respectively for the t-tests and 99% confidence interval was set for the prediction interval. Post-hoc power analysis identified that the 1-sample *t*-tests were able to detect minimum differences ranging between 0.9° and 1.9° from zero for the alignment measures and 0.57mm for cut depth with 95% confidence and alpha set a-priori at 5%. All statistical analyses were performed using Minitab (version 16, Minitab Inc, MA, USA).

RESULTS (fig. 2)

The fitting of the PSCB was adequate in every case for the femur and tibia. The planned size matched the surgeon's decision in 52% and 50% of cases for the femur and tibia, respectively. In the cases that did not match, the planned size was a size too small 23.3% of the time for the tibia and 28.3% of the time for the femur.

The proportion of differences between the planned PSCB alignment and the intraoperative measurements for the femoral block within ±3° and ±2° was greater for the coronal plane than in the remaining planes (Table 2). The

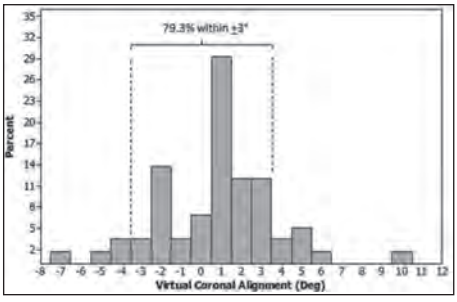

Fig. 2 : Total coronal alignment.

Table 2 : Differences between planned alignment and alignment recorded from the VISIONAIRE PSCB intraoperatively (°).

	Mean	P-value	Range	% within +3°	% within +2°	99% PI
Femoral						
Coronal	-0.2 + 1.8	0.41	-4.0, 3.0	94.8	79.3	-4.9, 4.5
Sagittal	2.1 + 2.8	<0.01	-5.0, 9.0	65.4	49.1	-5.5, 9.7
Rotation	0.6 + 2.5	0.09	-6.0, 6.5	77.2	68.4	-6.1, 7.3
Tibial						
Coronal	0.6 + 1.9	0.02	-3.0, 10.0	86.2	75.9	-4.4, 5.6
Slope	-0.1 + 2.6	0.78	-5.0, 11.0	80.7	59.6	-7.2, 7.0
Total						
Coronal	0.6 + 2.9	0.15	-7.0, 9.5	79.3	55.2	-7.2, 8.3
Sagittal	2.3 + 4.0	< 0.01	-5.0, 11.0	54.5	32.7	-8.4, 13.0

performance of the PSCB for tibial alignment followed a similar pattern. The sagittal slope displayed a larger range of values and a reduced proportion of the sample within the 2°-3° tolerance thresholds, compared to the coronal alignment (Table 2). When the femoral and tibial alignments were summed to produce a virtual limb alignment, the PSCB would have placed 79.3% of the sample within ±3° and 55.2% within ±2° of neutral (fig. 3). The total sagittal alignment results were marked, with 54.5% and 32.7% within ±3° and ±2°, respectively (Table 2).

The mean difference between planned coronal alignment and intra-operative navigation measurement collected preoperatively did not differ significantly from zero (0.6±2.9, p=0.15) although individual differences ranged from −7° to 9.5°. The 99% prediction interval for a single future measurement ranged from −7.2° to 8.3°. The size of bone resection was similar for the medial and lateral distal femoral cuts (Table 3). The range for the difference between the planned and the measured resections was larger for the distal lateral cut, while the distal medial cut displayed a wider prediction interval (Table 3). The PSCB was within ±2mm of the plan for 87.7% of the sample for both femoral cuts. The mean differences between the plan and the measured medial and lateral tibial resections were not significantly different to zero (Table 3).

DISCUSSION

The hypothesis that the VISIONAIRE PSCB system evaluated in this study is accurate was not supported by the results. The PSCB resulted in restoration to within 3° of the planned coronal limb alignment in only 79.3% of cases and of sagittal limb alignment in 54.5% of cases as measured by intra-operative computer navigation. Femoral component rotation was within 3° of the surgical trans-epicondylar axis in 77.2% of cases. Whilst this compares favourably with the accuracy of traditional jigs [3, 4], it does not approach the accuracy achieved with computer navigation [5, 6].

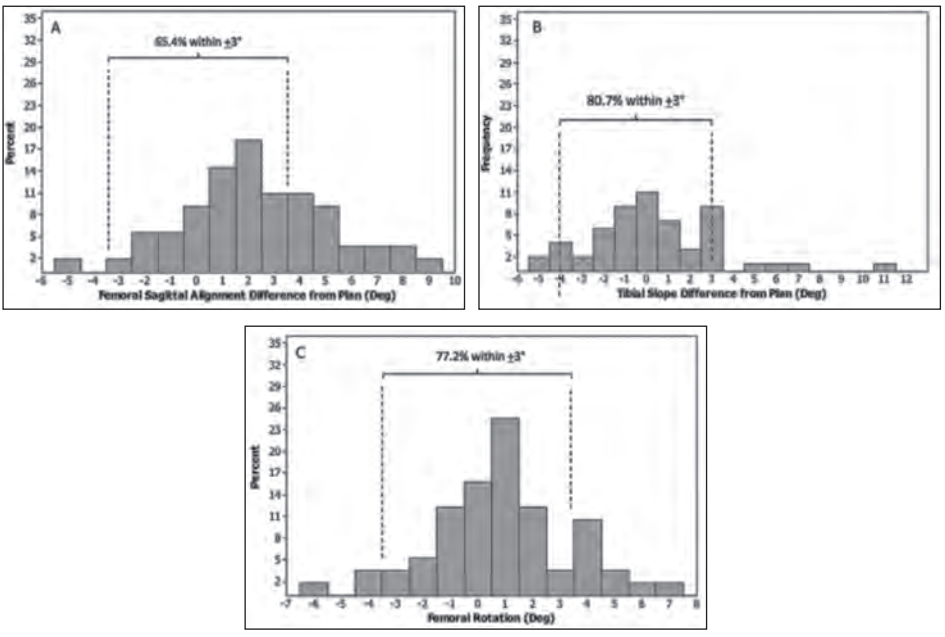

Fig. 3 : Sagittal alignment for the femoral (A) and tibial component (B) and rotational alignment of the femoral component (C).

Table 3 : Differences between planned bone resections and bone resections recorded from the VISIONAIRE PSCB intraoperatively (mm).

	Difference	P-value	Range	% within +2mm	% within +1mm	99% PI
Femoral Resection						
Distal Medial	0.0 + 1.2	1.0	-3.5, 6.5	87.7	70.2	-3.3, 3.3
Distal Lateral	0.25 + 1.1	0.1	-6.5, 6.5	87.7	66.7	-2.7, 3.1
Tibial Resection						
Medial Plateau	0.09 + 1.2	0.57	-6.0, 3.0	92	78.9	-3.0, 3.2
Lateral Plateau	0.08 + 1.1	0.60	-7.0, 3.0	93	78.9	-3.0, 3.2

Potential sources of error in VISIONAIRE cutting block design may include image acquisition and interpretation of the 3D image using MRIs about the knee joint limited to a 22cm field of view (11cm proximal and 11cm distal to the joint line). This perhaps explains the greater variation between the planned sagittal alignment and the operative measurements of the femoral and tibial resections. The anterior bow of the femur would tend to flex the apparent femoral sagittal alignment measured from limited distal MR slices (mean value ±2.1°), whilst the variation in physiological posterior slope of the tibia [7] would have an unpredictable effect on the estimation of pre-operative tibial sagittal alignment and therefore on the tibial resection (mean value −0.1°, range −5° to +11°). Another potential reason for inaccuracy could be the error during the application of the PSCB on the bone by the surgeon, even if the fitting was reportedly good in every case for the 60 patients in our study [8]. While the present results quantify the error between the plan and the blocks intraoperatively, the source of the error remains to be identified. Nevertheless, the results strongly suggest that the accuracy of the system is inadequate for clinical use without objective verification of alignment [9].

CONCLUSION

The VISIONAIRE PSCB system evaluated in this study displayed unsatisfactory accuracy in the coronal plane and even less accuracy in the sagittal and rotational planes. While the present study has quantified the error between the pre-operative plan and the alignment derived from the cutting blocks intraoperatively, the source of error remains to be identified. We speculate that limitations with the pre-operative imaging protocol and its integration within the planning process may provide opportunity for further refinement. Nevertheless, despite the potential of the system, the accuracy is inadequate for clinical use without objective verification of alignment. Further evaluation and protocol refinement are necessary to avoid exposing patients to the risk of poor outcomes due to malalignment following total knee arthroplasty.

LITERATURE

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PLACE OF NAVIGATION IN 2014: WHY I RESOLUTELY NAVIGATE ALL MY TKA?

D. SARAGAGLIA, A. KRAYAN

Navigation for total knee arthroplasty (TKA) is currently used all over the world. We implanted for the first time a computer-assisted TKA on January 21, 1997. Since March 1999 we have been using navigation for all TKA we perform. We published a prospective randomized study in 2001 [1] and currently, in my department, navigation is used not only for TKA, but also for osteotomies around the knee, UniKA and UniKA revision. We use a non-image based device (Orthopilot™, B-Braun-Aesculap, Tuttlingen, Germany) and the operative procedure was well described in several publications [1, 2, 3].

Today, despite the fact that this technology improves the accuracy of the implantation of the prosthesis [4, 5, 6, 7, 8, 9] and allows to reach more easily the pre operative goal, navigation has not had the development one could hope. Users can be estimated at 30% in Germany, 5 to 10% in France and 5% in Great Britain. Some surgeons are very enthusiastic, others are indifferent or against [10]. However, enthusiasm for this innovative technology is still present as more than 200 articles have been published over the past 3.5 years.

HISTORY OF TKA NAVIGATION

Computer-assisted surgery began with stereotactic neurosurgery [11] towards the end of the 1980s. This new technique had for aim to improve the precision of operations, reduce surgical invasivness and improve the traceability of interventions.

The history of computer-assisted implantation of total knee prostheses dates back to 1993 when we set up a work group including 2 surgeons (D. Saragaglia and F. Picard), 1 medical doctor/computer scientist (P. Cinquin), 2 computer scientists (S. Lavallée and F. Leitner) and an industry partner, which was at the time I.C.P France (bought-over by Aesculap-AG, Tuttlingen, Germany, in 1994). In our first meeting the senior surgeon (DS), drew up the specifications defining computer assistance for TKA. A pre-operative scan was not needed to guide surgical navigation for several reasons: this was firstly because, at the time, this examination was not part of the pre-operative check-up required for a knee prosthesis, secondly, we felt that an examination

of this sort could only complicate the operative procedure and lastly, this would have added additional cost and a considerable amount of radiation exposure for the patient. We needed to have a reference to the mechanical leg axis throughout the whole operation so that the cutting guides could be placed perpendicular to this axis in a frontal and a sagittal plane. The cutting guides needed to be placed freehandedly without any centro-medullary or extra-medullary rods. Finally, the operation was not supposed to last more than 2 hours (maximum tourniquet time) and the procedure was to be accessible to all surgeons, whatever their computing skills.

The project was assigned to F. Picard, as part of his Postgraduate Diploma in Medical and Biological Engineering, and to F. Leitner a computer scientist who was completing his training. After 2 years of research, the system was validated by the implantation of 10 knee prostheses on 10 cadaver knees, and the results were published in 1997 [12, 13] in several national and international publications, including CAOS, SOFCOT and SOBCOT.

After obtaining consent of the local ethics committee on December 4, 1996, the first computer-assisted prosthesis was implanted in a patient on January 21, 1997 (D. Saragaglia, F. Picard, T. Lebredonchel). The operation lasted 2 hours and 15 minutes and was uneventful.

A prospective randomized study comparing this technique to the conventional technique began in January 1998 and was completed in March 1999. The results were published in several national and international meetings and in a lead article in the French Journal of Orthopaedic Surgery [1]. In March 1999, the prototype that we had used in this study evolved to a final model called Orthopilot™ [B-Braun-Aesculap, Tuttlingen, Germany]. The software packages have evolved over the years but the basic principle has remained the same since the system was created. To day, in our hands, computer-assisted TKA takes around one hour (from 50 to 75 minutes) and is routinely used.

WHAT HAVE I LEARNED WITH NAVIGATION?

Navigation is probably the best tool to teach the implantation of TKA. During the operation, the fellow can follow exactly the operative procedure and familiarize with the HKA angle, the femoral mechanical angle (FMA), the reducibility of the deformity, the tibial slope, the need to do a release or not or to give rotation or not to the femoral implant. All these data are analysed in live and discussed during surgery. Moreover, for a young surgeon with little experience, the learning curve is much less long than for conventional technique [14].

In my own practice, I learned that I could reach the goal I wanted to reach preoperatively in an easier way. In other words, whatever the HKA angle, included severe varus or valgus deformity, navigation allows the final HKA angle to be within 3° residual valgus or varus deformity in more than 95% of the cases.

Regarding the tibial cut, navigation is not very different from conventional technique except that it is more precise than extra, intra or combined extra and intra medullary guides. For the distal femoral cut, we have learned that the medial FMA is not always in valgus and it can range from 10° of varus in some severe genu varum deformities, to 10° of valgus or more in some severe valgus deformities. In these severe conditions, above all for genu varum, the intra medullary guides do not allow to give sufficient valgus in order to put the femoral implant perpendicular to the mechanical axis of the lower limb (fig. 1).

I have learned also that, in case of severe deformity, the varus or the valgus can be reducible or over reducible avoiding to perform extensive releases [15]. It is the reason why, currently, in my hands, extensive release is around 5% of the cases and I do pie crusting of the medial collateral ligament (genu varum) or fascia lata (genu valgum) also in around 10% of the cases.

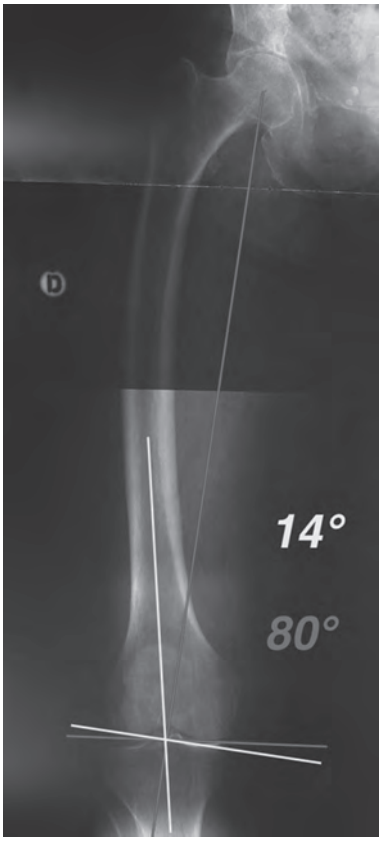


Fig. 1: Severe varus deformity of the femur. The medial FMA is at 80°, that is 10° of varus. It is impossible to put the femoral implant at 90° with a conventional ancillary without tricking with the intra medullary rod… It is very easy with navigation…

Navigation modified also my way of thinking when regarding the rotation of the femoral implant. Currently, I externally rotate the femoral implant in only 10% of the cases and even I do not hesitate to internally rotate the implant in 2% of the cases. External rotation is given when the FMA is in valgus (above 3° of valgus) and when the flexion gap is tight on the medial side or lax on the lateral side. Internal rotation is given when the FMA is in varus (above 3° of varus) and when the flexion gap is lax on the medial side. In the other cases, the femoral prosthesis is implanted parallel to the posterior bicondylar line with no additional rotation.

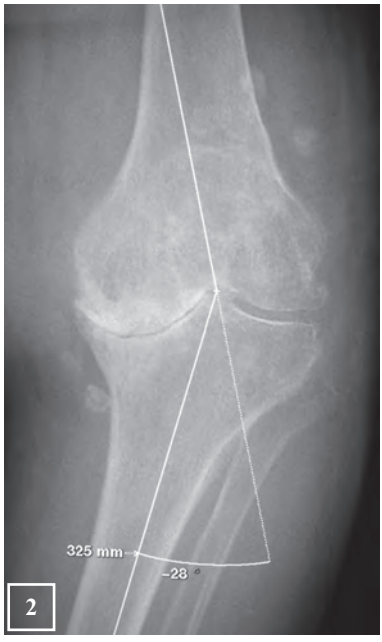
Finally, navigation is very interesting to evaluate the sagittal balance of the knee that is flexum or recurvatum, which is not so easy to measure before and after the implantation of the prosthesis with a conventional procedure. In these cases, navigation allows to cut less or more bone of the distal part of the femur in order to fit exactly the prosthesis to the extension gap and to avoid too much recurvatum or flexum.

WHY I RESOLUTELY NAVIGATE ALL MY TKA?

Considering everything I've learned in 17 years, it seems difficult to do TKA without navigation. The best indications to use navigation are severe deformities (fig. 2, 3, 4, 5), malunions of the tibia or the femur [16, 17] (fig. 6, 7, 8, 9 10) and when there is unremovable femoral hardware [16, 18] (fig. 10, 11, 12). However these indications are not so frequent and if one only uses navigation for these rare cases, the procedure will be very boring and time consuming for the surgeon and his entourage. We do well what we do often!

CONCLUSION

Currently, Computer-assisted TKA is performed routinely in my department as well as osteotomies of the knee, UniKA and UniKA revisions. All the staff of the operative room is well aware of the functioning of the device and no time is lost around the operation. It is not harder to manage than an arthroscopy of the knee. There is no preoperative constraint to the surgeon or his team and all decisions are taken intraoperatively. Despite this fact, the procedure takes only 5 to 10 minutes more that is negligible, compared to all the benefits.



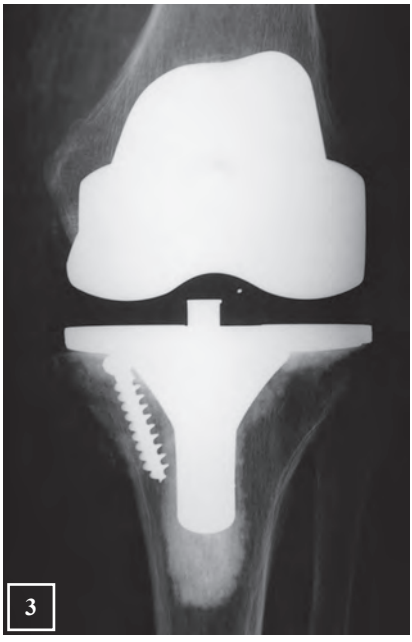
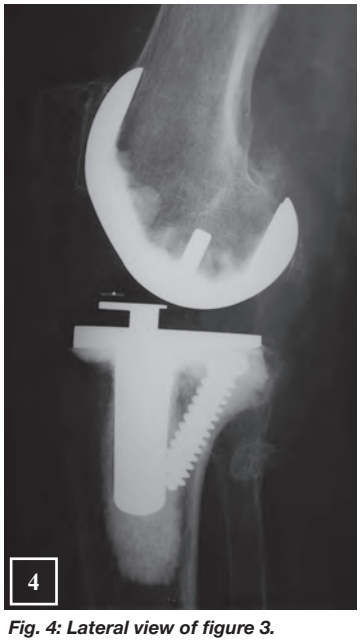
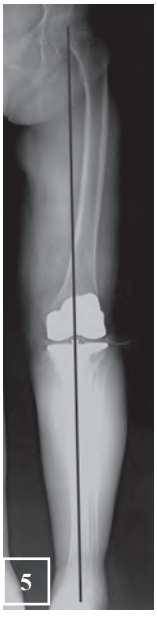


Fig. 2: Severe genu varum deformity with bone loss of the tibial plateau. The varus was reducible from 28° to 3°!
Fig. 3: Computer-assisted TKA of figure 2 case. A screw was used as a pillar and a mobile bearing PCL retaining TKA was implanted without any rotation and with only a pie crusting of the medial collateral ligament.





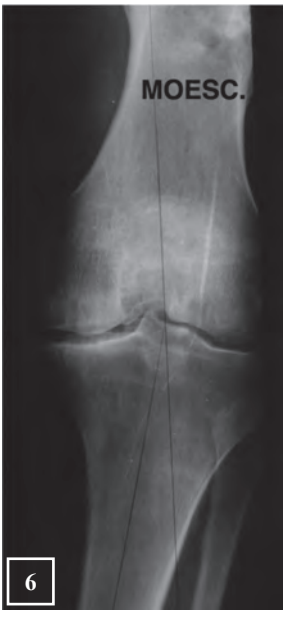
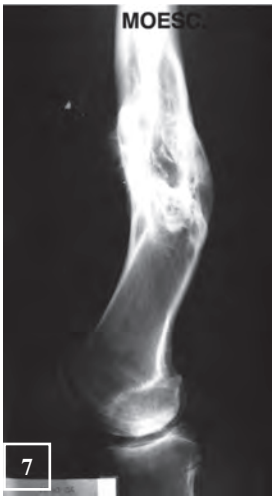
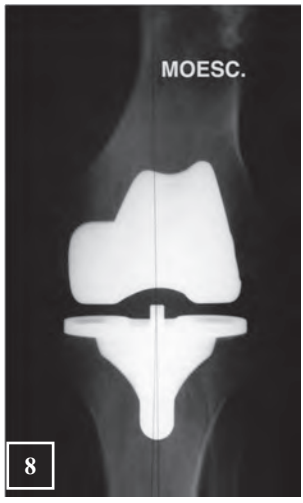


Fig. 4: Lateral view of figure 3.
Fig. 5: Standing long-leg xRay of figures 3 and 4: HKA at 180°.
Fig. 6: Medial osteoarthritis of the knee occurring on a recurvatum malunion of the distal part of the femoral shaft.





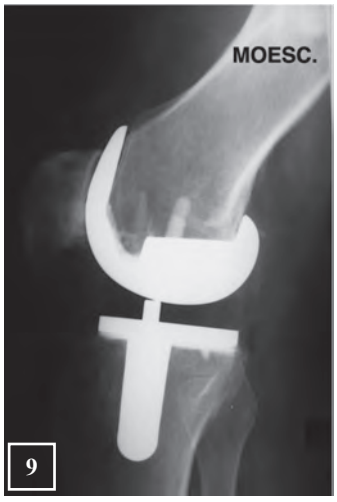
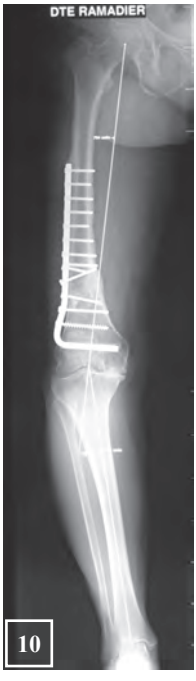
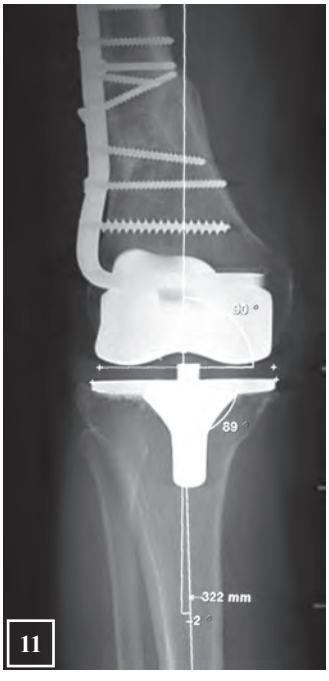


Fig. 7: Lateral view of figure 6.
Fig. 8: Computer-assisted TKA performed in 1999 for figures 6 and 7 case.
Fig. 9: Lateral view of figure 8 case. Notice that the computer placed the femur in flexum to correct the recurvatum.





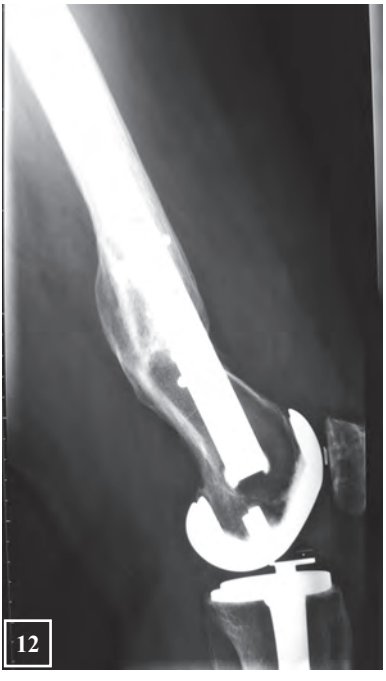


Fig. 10: Knee osteoarthritis under a plate, which was implanted 20 years previously. To remove the plate is not advised because of the risk to lead to recurrent fracture. Moreover, there is also a recurvatum malunion (see figure 12).
Fig. 11: Computer-assisted TKA of figure 10 case, avoiding to remove the plate.
Fig. 12: Lateral xRay of figure 11 case.

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KNEE NAVIGATION IN KNEE ARTHROPLASTY IN 2014
15 years of experience

F. PICARD, F. LEITNER, A. GREGORI, D. SARAGAGLIA

INTRODUCTION

On the 21st of January 1997, the first ever navigated total knee replacement (TKR) was performed in Grenoble, France. After ethical approval, five patients underwent CT-free navigation surgery and the preliminary results were published in CORR in 1998 [1, 2]. Since then, several companies have developed, implemented and improved robotics assistive and computer-assisted systems to help orthopaedic surgeons to navigate knee arthroplasties. With the advance of medical imaging technology, mechatronics, and haptic technology, several surgical and scientist teams have conceived instruments that can help surgeons to perform more accurate and more precise orthopaedic surgical procedures. Total knee arthroplasty (TKA or TKR) is described in this article as it is the joint most often navigated procedure but many other surgical procedures are performed using Computer Assisted Surgery (CAS) such as Total Hip Replacement (THR), High Tibia Osteotomy (HTO), Distal Femoral Osteotomy (DFO), Anterior Cruciate Ligament Reconstruction (ACLR), or even Spine and this list is not exhaustive [3, 4, 5, 6].

In orthopaedics, the pioneers were undoubtedly spine surgeons associated with neurosurgeons who were quickly involved in the concept of image-guided surgery, mainly to secure pedicle screw placements and complex sacro-iliac fixations [7, 8]. At the same time, innovators in California brought active robotic instrumentations in theatre in order to facilitate the intra-femoral medullary canal preparation to fit perfectly any femoral stem [9]. The computer's power, which according to Moore's law almost doubled every eighteen months will be as powerful as a human brain by 2020 [10] and has contributed complex and sophisticated tool designs available to the orthopaedic surgeons tool-box [11].

In spite of increasing advances of technology, CT-free or image free also named non-image based navigation still dominates other types of systems in CAS total knee arthroplasty (TKA) [12, 13]. Several reasons are allotted to the success of CT-free navigation such as its reliability equating CT-based navigation's reliability, its user friendliness, no need for pre-operative data acquisitions (i.e. CT or MRI scans) [14, 15]. However, even though this technology has been through several cycles of trials and errors, as well as substantial enhancements such stream lined software or ergonomics simplification, this technology is still not mainstream yet [16]. The National Registry of countries, such as Australia (>8%), England (<3%) or Norway (<5%) are all showing limited numbers of computer-assisted

knee technology users [17]. Numerous reasons explain why this technology is still not used more routinely and widely in orthopaedics. In a recent publication, we identified two obvious explanations: one is the lack of optimal ergonomic systems for most of them and the second is economical [18].

Regarding the ergonomic of CAS systems, most of them have been developed through engineering cycles of improvements with little input from surgeons, which have produced sometimes very sophisticated but also very complex solutions to navigate straightforward surgery such as TKA. On the other hand, orthopaedic companies and furthermore the "majors" have not been much interested in developing tools in this field (i.e. camera, electronics devices, software…) which are out of their domain of competencies (i.e. prosthetic design, metallurgy or mechanical ancillary instrumentations…). Therefore, the lack of input from orthopaedic surgeons combined with cautious investments from orthopaedic companies [19] have slow down attraction to the field. Moreover, a sluggish marketing compared to Minimally Invasive Surgery (MIS) for example made the introduction of this technology very timid. It is also true that MIS was an easier concept to sell to surgeons and patients than CAS !

However, two recent key events have changed the perception of this technology from all players in the field and may have allowed CAS to pass the chasm between early adopters and mainstream orthopaedic users. The first is the acquisition of an autonomous robotic haptic assistive tool, named MAKO (Fort Lauderdale, Florida US) by a major orthopaedic company (Stryker, Kalamazoo, US) [20]. Stryker is the number one world company in orthopaedics and they bought MAKO for 16.2 billion dollars (!), which clearly suggests a dramatic change towards the technology in the field of orthopaedic surgery. The second event is the publication of the 2013 Australian Registry outcomes showing a statistical difference reduction of knee revision after 6 to 9 years follow-up, in young navigated TKA patients (less 65 years old) in comparison to conventional TKA [21]. These results would require confirmations from other sources, albeit being striking. Although navigation is hence a mature technology, it still needs to go through usual phases of adoption [22]. On the other hand, computers are everywhere and it is unlikely that orthopaedic surgical theatres will escape the changes.

In this article, we would like to describe the phases we went through over the last fifty years with this technology and describe the benefits, as well as the drawbacks that have been raised all along the way using navigation on knee arthroplasty.

Looking back, we can categorise five identifiable phases in my practice with CAS (Computer assisted Surgery/Computer assisted navigation) for TKA:

1. Prototypal phase
2. Measured resection technique
3. Gap management software development
4. Refinement of the technique and intelligent use of data collection
5. New tools in the surgical tool box.

PROTOTYPAL PHASE

In the 1990s, most of the teams who were working on computer-assisted technology in the field of orthopaedics were strongly focused on robotics and image-guided technology [23, 24, 25]. Therefore, the concept of CT-free navigation using only intraoperative anatomical and kinematical data straight from the patient's anatomy was a little bit disruptive. Patient's frame of reference was built from immediate data collection and did not require to establish any complex registration or matching process imposing convoluted mathematical computation. The concept was quite odd and provocative because it was deescalating the natural evolution of complex technology and software engineering process. It took a long time to develop technical and software tools to become a usable and reliable system, which could then be used in routine practice. Once the system was available, a few teams in the world started to evaluate the principles in view to reproduce

and improve the device [26, 27]. The original goal of this tool was to reproduce more consistently the recommended leg alignment for TKA, which has always been considered as an important factor for long-term survivor of knee replacements even if this concept is yet debated [28, 29].

At the beginning of the 21st century, a few competing navigation systems were out there and offered to knee arthroplasty surgeons. Despite the appealing attraction to robotic or complex CT-based navigation systems, CT-free navigation systems were preferred and gained popularity in the orthopaedic community [30, 31]. However, the tools developed at the time were still rudimentary and sometimes very primitive in some of the systems, which made the surgeon's work more difficult and disruptive than the use of even complex conventional instrumentations. Nevertheless, at the end of this prototypal phase four steps were clearly identified in any CAS System: Set-up, Registration, Planning and Execution [32, 33].

The set-up step is the fundamental step of fixing markers in the bone to refer any anatomical landmarks or proceed for any sort of registration. Several solutions have been proposed, including pins, K-wires, small drills, bi-cortical screws, etc, to secure trackers in the bone that will stay from the beginning until the end of the surgery [34]. A lot of options given to surgeons were very cumbersome, sometimes not reliable, most of the time not user-friendly at all and most of all were time consuming!

Registration step is the second step consisting in collecting anatomical and/or kinematical landmarks to build a frame of reference straight from the patient's anatomy, which were then used for CT-free navigation. The other alternative was to use some of these landmarks to match the pre-operative patient's CT data to build an image-guided frame of reference. CT-free navigation technique did not required any preoperative CT scan from patients which was a major advantage with respect to CT-based navigation. In addition to that, the compulsory matching process to combine the patient's anatomic data to the pre-operative 3-D imaging reconstruction was a complex mathematical process, which was still under evaluation.

Planning is the third step, which was easy to do and probably the nicest feature with CT-based navigation. For CT-free navigation, the planning step was at its very early stage of evaluation. Later this phase was developed and implemented very extensively and we will elaborate on that aspect later. However very basic planning such as implant sizes was already available and displayed.

Execution is finally the last and fourth step which was done by surgeons using computer guided conventional instrumentations. It was clear that the set-up and registration phases were very disruptive, in comparison to conventional instrumentation, and changed the way surgeons performed the surgery. Some of the systems were more advanced than others and I was lucky enough to use a system which allowed us to complete knee replacements without any major disruption with respect to conventional surgery from the beginning to the end of the surgical procedure. The main reason of that was because the development of the computer assisted tool was done to follow conventional instrumentations without trying to disrupt the usual surgical flow.

The prototypal phase was the phase where enthusiastic innovators enjoyed to explore the field. Many things were set at that stage such as the computer usability in theatre, the use of infrared technology and the four steps described above. However the tools were still crude and the surgeons had to adapt to the machine and not the opposite. Nonetheless a full TKA could be performed within reasonable time with good precision and accuracy.

MEASURED RESECTION SOFTWARE

The basic concept on which this system relied on was the measured resection technique. The system was developed in order to help the surgeon to reproduce with high precision and

accuracy the desired leg alignment, which was defined as 180° femoro tibial mechanical angle, with the femoral and the tibial components placed respectively to 90° with respect to the femoral and tibial mechanical axes. This technology was used at such an early stage, that users were very anxious, to not say suspicious of the numbers displayed on the monitor screen, in spite of extensive laboratory experiments [35, 36]. However, very limited number of patients had been done with computer-assisted navigation at that time and therefore the outcomes were unknown. This phase was very stressful and time-consuming because not all clinical situation had been tested before, so that conventional instrument was also used to control any computer recommendations. It took few years of trial-errors testing before the system was considered as fully reliable. Meanwhile, each phase of computer-assisted navigation technology, i.e. set-up, registration and planning described above were improved in the view of facilitating the work of arthroplasty surgeons. On the other hand, there was still a great need for improvements for user-friendliness of the technology compared to conventional surgery. Most of the studies at the beginning of 2000 showed that navigation was clearly time-consuming [about 25% more than traditional/conventional surgery] and was also very disruptive, which put off most of the arthroplasty surgeons from the technique.

Later, a study has confirmed that CT-free navigation was as good as CT-based navigation [12], which made the tool more appealing because there was no need for any pre-operative medical imaging, which were expensive and time-consuming. The registration became slightly easier, slicker and provided reliable frame of reference on which the surgeon could navigate the jigs to cut appropriately the distal femur and the proximal tibia. Numerous publications including meta-analysis confirmed statistical improvement of leg alignment, coronal and sagittal implant positions with the use of CAS with respect to conventional instrumentation [37, 38, 39]. However there was still controversies regarding CAS usefulness on functional outcomes and long term implant survivorships [40]. Obviously no one could answer these relevant questions because the technique was still to its infancy stage. However, users could meanwhile analyse the benefit of this technique on soft tissue management, which is a known as a key factor to TKA success.

SOFT TISSUE MANAGEMENT SOFTWARE

The advance of new software enabled the surgeons to assess flexion and extension gap of the knee more accurately than before after the tibial cut resection [41, 42]. Computer assisted measurements allowing measuring flexion and extension gaps between the femur and the resected tibia very accurately. Most importantly, with such planning feature the surgeon could plan the full distal femoral cuts before any actual cuts were even performed [43]. We used more and more this software in the more complex cases, such as fixed flexion contracture valgus knees. Soft-tissue management in these knees is very challenging. This technology does provide a very accurate intra-operative measuring soft tissue envelope tool to fine tune and tailor soft tissue release during TKA. Some of my colleagues continued to use the measured resection technique, while some others used uniquely the gap management technique. Personally, I used one or the other depending on the patient's case complexity. Clearly this type of instrument allowed us to improve the way we assessed the knee and gave us immediate feedback on the necessary sequential release that had to be performed to ideally align and balance the knee. It is striking to see how different each knee is to the next one and to observe, as well, how two similar pre-operative knees (i.e. examination and x-rays) would react completely differently to stress measurements using accurate CAS assessment and guiding. From there, several teams have developed algorithms to ideally balance the knees [43, 44, 45].

REFINEMENT OF THE TECHNIQUE AND INTELLIGENT USE OF DATA COLLECTION

After assessing and reviewing at length our knees during and after computer-assisted surgery, it became obvious that more work needed to be done regarding the frame of reference acquisition in order to improve for example the femoral or tibial rotations which were not well defined [46, 47, 48]. Secondly, it was also evident that the introduction of accurate intraoperative tool for patient's assessment was good but still only identified a partial view of the "whole picture" of the patient. For example, intraoperative tool were assessing non weight bearing knee kinematics [49, 50, 51, 52, 53]. Thirdly any reconsideration of the concept of leg alignment or soft-tissue balancing in knee arthroplasty would require accurate intra and perioperative measurements [54, 55].

Our work has been concentrating on assessing more carefully the anatomical landmarks use for femoral and tibial component rotation [56, 57, 58]. Few teams around the world had similar approach. Siston *et al.* reassessed completely the CT free navigation concept and analysed the optimal landmarkings to build reliable and reproducible frame of references [46, 47, 59]. One of the most remarkable findings was to show evidence of the effectiveness of combined landmarks to define the femoral and tibial rotation. Some others like Victor *et al.* did tremendous work to evaluate soft tissue envelop properties using CAS [60]. We were also keen to use CAS as an algorithm management tool for soft tissue management. Other teams had similar approaches [43, 44, 55].

The second issue was the inadequacy between intraoperative data, even accurate, and preoperative condition or postoperative kinematics. That is the reason why our team, and others, have worked extensively on the evaluation and development of non-invasive CAS that would provide a true picture of dynamic patient kinematics. Our work proved that, alignment and tissue envelop laxity (within 40 degrees) could be recorded very accurately and precisely using non-invasive technology. Furthermore this system was based on software modules identical to the invasive CAS technique meaning that most of the measurements taken with non-invasive and invasive systems were identical. Therefore, for the first time, a non-invasive system could assess knee kinematics in more realistic conditions (i.e. standing full weight bearing or under varus or valgus stress) which would help to adjust more appropriately intra-operative soft tissue management. As mentioned already the varus/valgus envelope could be reliably measured within the first 40° of flexion, which was enough to detect mid-flexion instability. These tools still in development are certainly key to the success of future knee arthroplasty surgery [49-54].

In at least two of our studies, we clearly demonstrated that there is a difference between the supine alignment and standing alignment which means that maybe the ideal a leg alignment after TKA should be 2 or 3° of valgus instead of 0° (180 degrees) to conform to a balanced knee. However, whatever the goal, CAS proved to be an invaluable device to set whatever angle has to be done to optimize the knee functional outcome. Uncertainty still remains as far as functional outcomes are concerned after CAS TKA.

THE NEW GENERATION OF CAS FOR A SAVVY GENERATION [61]

The frame of reference used to guide knee replacement in CAS has been extensively validated and confirmed to be very reliable and very reproducible to orient the jigs and implant components. Most of the CAS systems used today are infra-red (IR) technology and showed

excellent accuracy and precision within 1° and 1mm. Several alterations of IR technology went through multiple cycles of improvements and other options such as electronic magnetical (EM) tracking or ultrasound technologies aroused but were not as successful and, more importantly, not as accurate and reliable than IR technology [35].

CAS in knee replacement confirmed over the years its benefits on leg alignment, component position, reduction of surgical invasiveness such as blood loss and fat embolism reductions without increasing the number of complications [62, 63, 64, 65]. Most recently, a few studies showed improvement in short term functional outcomes and lower revision rate with the use of CAS in TKA [66, 67, 68]. Accurate intraoperative measurements has undoubtedly shed lights on current insufficiencies of conventional instrumentations [69]. The usual separation between measured resection and gap managements techniques is not satisfactory and CAS is currently generating thousands of datasets that will help to understand more precisely the effects of each steps performed during these two techniques. Indeed, mid-flexion instability and unpredicted knee kinematics are still issues to be solved to improve TKA results [70]. For years, brilliant scientists have done a kind of reverse engineering in analysing a multitude of factor of knee anatomy, investigating knee kinematic characteristics to design better implant and instrumentations. However, there is an obvious discrepancy between current knee biomechanical knowledge and what is really applicable in surgery. Navigation is certainly filling the gap between the two.

More recently, robotic came back stronger than before. Significant technical innovations have made these tools more reliable, more user-friendly and more ergonomically fit to normal orthopaedic surgical practice. One of the most recent tools is the PFS robot (precision free-hand sculpture robot), which is the first handheld robot using CT-free navigation technology. This tool relies on concept already described above, with four phases (set-up, registration, planning and execution) and the use IR technology. This small new robot is one of numerous technological tools that are now available to surgeon to secure the knee replacement procedures [71, 72].

CONCLUSION

I was lucky enough to be part of the birth of CAS in TKA following all early developments that are now accessible to any surgeon. These tools have been through extensive cycle of evaluation, trial and error processes, and have now reached maturity. Most of these systems can now be used on a routine basis as any conventional instrumentation to perform TKA. I personally went through five phases so far:

1. Prototypal phase
2. Measured resection technique
3. Gap management software development
4. Refinement of the technique and intelligent use of data collection
5. New tools in the surgical tool box.

Each of them has brought technical advances, more knowledge in knee anatomy and kinematics and finally improvement of TKA outcomes.

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ROBOTIC SURGERY: EXPERIENCE WITH UNICONDYLAR KNEE ARTHROPLASTY

S. LUSTIG, P. NEYRET

Surgical robotics has been shown to improve the accuracy of bone preparation and soft tissue balance in unicondylar knee arthroplasty (UKA). However, although extensive data have emerged with regard to a CT scanbased haptically constrained robotic arm [1], little is known about the accuracy of a newer alternative, an imageless robotic system.

The Navio™ Precision Freehand Sculpting system (Navio™ ; Blue Belt Technologies Inc, Plymouth, MN, USA) is an imageless handheld robotic tool (fig. 1). Implant planning and development of the cutting zone take place entirely intraoperatively without the need for a preoperative CTscan. The system continuously tracks the position of the patient's lower limb and the handheld robotic device using an infrared navigation system. The system is imageless in as much as it does not use a CT or MRI to map the femoral and tibial condylar surface. It therefore relies on accurate registration of intraoperative knee kinematic assessment, anatomic landmarks, and surface mapping of the knee using a calibrated optical probe designed for use with this robotic system.

After percutaneous insertion of bicortical partially threaded pins into the proximal tibia and distal femur and attachment of optical tracking arrays (fig. 2), mechanical and rotational axes of the limb are determined intraoperatively by establishing the hip, knee, and ankle centers. Either the kinematic, anteroposterior (Whiteside) or transepicondylar axes of the knee are identified and selected to determine the rotational position of the femoral component. The condylar anatomy is mapped out by "painting" the surfaces with the optical probe. This registration process takes approximately 5 minutes on average. The intraoperative data then are used by the system's software algorithms to determine the coronal, sagittal, and axial bone axes and morphology.
A virtual model of the knee is created. Implant planning for component sizing, alignment, and volume of bone removal takes place intraoperatively (fig. 3). The surgeon selects the implant size that best fits the patient's anatomy

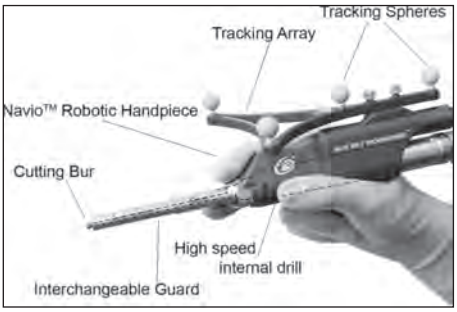

Fig. 1 : Navio™ handpiece

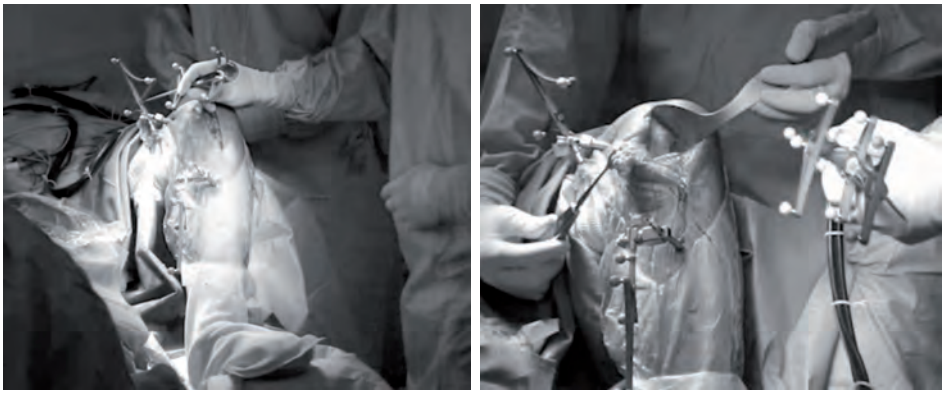

Fig. 2 : Surgical setting for a medial UKA.

and closely matches the size of the condyle to be replaced as well as its position in the coronal, sagittal, and rotational planes. Subsequent steps are directed at determining gap and ligament balance after virtual implant positioning, removal of osteophytes, and stressing of the ligaments and soft tissues. Osteophytes are excised and a dynamic soft tissue balancing algorithm is initiated. With an applied valgus stress to tension the medial collateral ligament (for medial UKA) or a varus stress to tension the lateral structures (for lateral UKA), the three-dimensional positions of the femur and the tibia are captured throughout a passive range of knee motion. A graphical representation of gap spacing through the range of flexion is created and determination is made regarding whether the planned position of the femoral and tibial component is adequate or adjustments can be made to achieve the desired soft tissue balance. By adjusting the implant position, including tibial slope, depth of resection, and anteriorization or distalization of the femoral component, the virtual dynamic soft tissue balance can be achieved. Adjustments in implant position and size can be made to optimize soft tissue balance and component tracking and position before beginning bone preparation (fig. 2).

Unlike predicate robotic technologies that provided haptic constraint through a robotic arm, this system works with a combination of speed and exposure control safeguards applied through a lightweight, handheld, surgeondriven semiautonomous robotic sculpting tool. In "exposure" mode, the 5- or 6-mm burr is continuously moving and is switched on and off by the user by pressing or releasing a foot pedal. A guard covers the burr, which only extends past the guard when the burr is in the "expected" cutting zone. The cutting zone is predetermined by the surgeon during the implant planning stage of the operation and the system modulates the exposure distance of the burr tip beyond the protective sheath. The position data are continuously updated in real time, resulting in fluid adjustments in the position of the burr tip. When the handpiece is moved out of the cutting zone, the burr retracts within the guard. The second control mode is "speed" mode in which the burr only becomes active in the cutting zone. The speed of the rotating burr is at full power/full speed until the intended bone is removed or it is moved beyond the desired preparation volume, at which point it linearly ramps down to zero. After planning for size, position, alignment, bone volume, and gap balancing, the arthritic cartilage and bone are methodically removed using the handheld sculptor. The depth of bone to be removed is color-coordinated, in which the target surface is yellow, the green surface indicates 1mm of bone still to be removed, the blue surface indicates 2mm of bone still to be removed, and the purple layer represents 3mm or more bone to be removed (fig. 4).

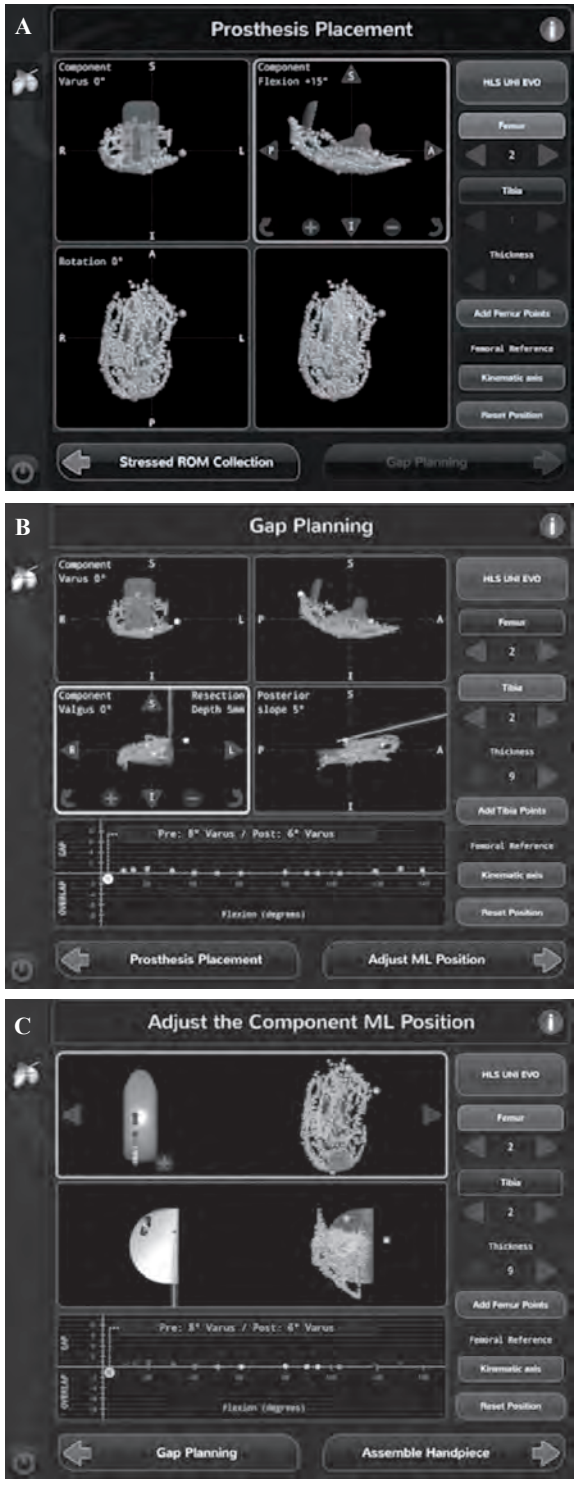

Fig. 3 : (A) The planning stage screen shows where the user can adjust the implant size and move the position of the implant in all three planes to best match the patient's condyle. (B) The gap planning screen shows the position of the implant on the patient's condylarsurface. The graph at the bottom of the screen illustrates the virtual gap balance through a range of motion predicted from implementing the planned implant position and tensioning the ligaments. (C) Contact point screen, illustrates the contact points on both the tibial and femoral component as the knee goes through a range of flexion.

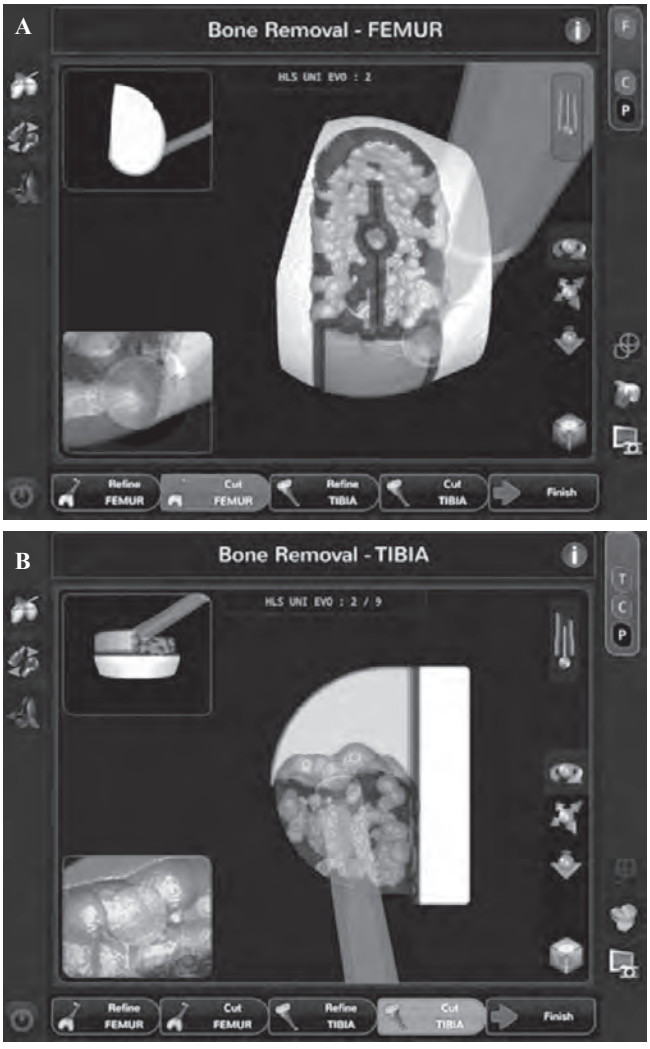

Fig. 4 : (A) Femur and (B) tibia cutting screens show midcutting. The yellow surface is the "target" surface, green surface indicates 1mm of bone still to be removed, blue surface indicates 2mm of bone still to be removed, and the purple surface indicates 3mm or more bone still to be removed.

Bone preparation is performed per the manufacturer's recommended technique for robotic UKA with the Tornier HLS UNI Evolution implants. The femoral component, with a central lug and keel, is impacted rigidly onto the prepared bone surface and the slotted trough and peg hole on the femoral condyle optimized positioning of the component. The tibial implant in this particular design is a cemented unconstrained all-polyethylene insert. This implant design has reported good clinical and radiological results [2]. It was designed without lugs or keel to allow variable positioning on the AP axis based on intraoperative assessment of positioning relative to the femoral component. Once the gap balance through a range of motion is checked with the trials (fig. 5). both components are cemented (fig. 6).

Our preliminary results with this system are comparable with those published from clinical studies investigating other semiautonomous robotic orthopaedic devices [3, 4]. A recent cadaver study has also found a high degree of accuracy with this technology [5], but future studies are still needed to determine the accuracy in clinical use compared with conventional techniques as well as functional outcomes and implant durability with this image-free robotic system, all of which are important elements of successful UKA.

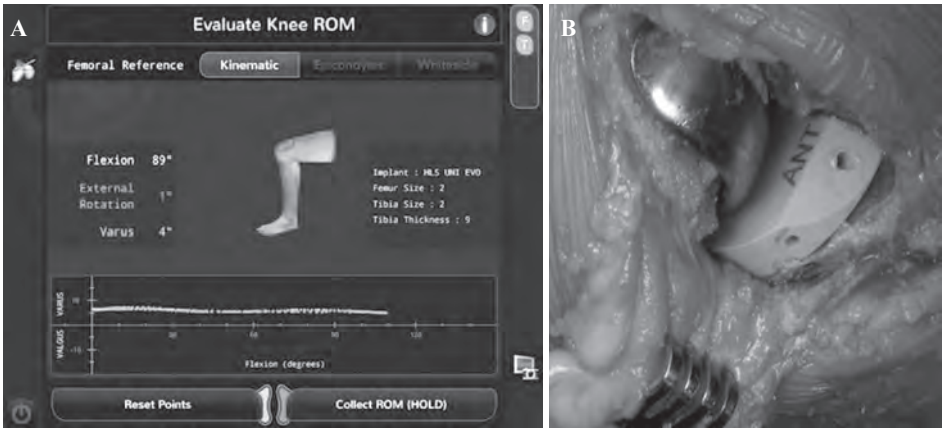

Fig. 5 : The gap balance through a range of motion is checked (A) with the trials (B).

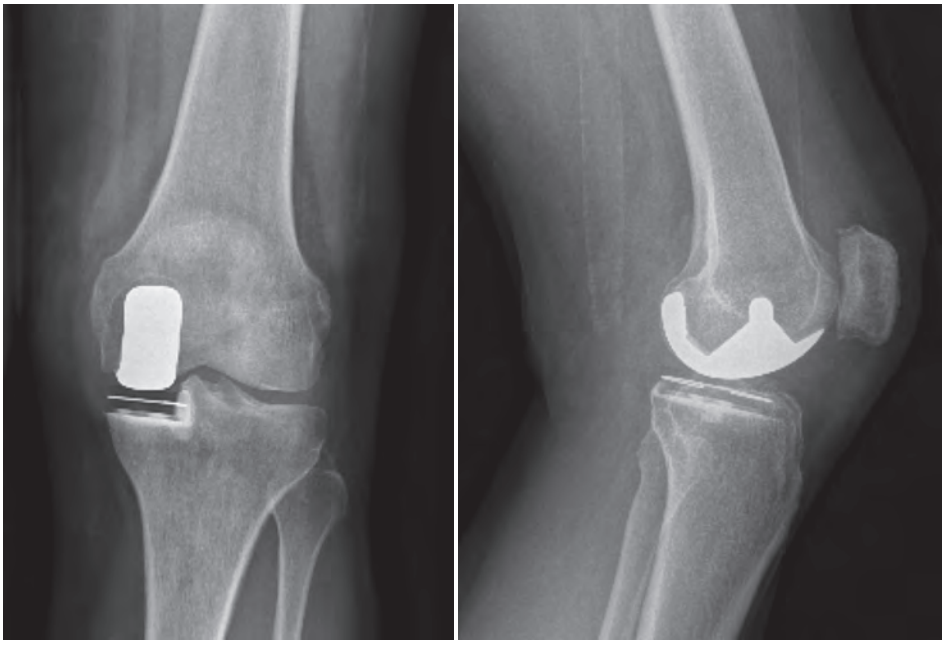

Fig. 6 : Post operative X-Ray.

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ROBOTIC SURGERY AND INTELLIGENT INTRUMENTS

PATELLOFEMORAL ARTHROPLASTIES

P. ERASMUS, K.J. CHO, J.H. MÜLLER

INTRODUCTION

Results of patellofemoral replacement (PFR) are poor and compare badly with TKR and UKR. The inferior results do not relate to prosthesis failure or loosening and only partially to progressive degeneration in the tibio femoral articulation. The poor results relate to the inability to place a PFR in the exact position to restore constitutional or natural tracking in a specific patellofemoral joint.

The patellofemoral joint differs from the rest of the knee in that it is individualized to each person, similar to a fingerprint. The reason for this is that the morphology of both the patella and its underlying trochlea is the result of the effect of "form follows function" [1]. This is the expression of the subtle individual differences in sagittal, coronal and rotational alignment of the lower limb as well as the effect of the angle and forces of the extensor muscles over the knee joint. As a result of these individual differences, it is almost impossible to design instruments and prostheses where one design fits all.

There should not only be a smooth transition between the trochlear prosthesis and the surrounding cartilage, but also the restored trochlear groove should have proper axial and rotational alignment. In order to achieve this, there should be an exact fit distally, medially and laterally. The fit on the surrounding articular cartilage will have an effect on the trochlear groove angle and the rotational alignment in both the axial and sagittal planes. In practice, there is often a conflict between good prosthesis articular transition and the correct trochlear groove and rotational alignment. In these situations correct axial and rotational alignment can often only be achieved at the expense of a bad prosthesis articular cartilage junction or vice versa. It is in this respect that: ***1)*** 3D based preoperative planning and predicted patella tracking, ***2)*** patient-specific instrumentation, ***3)*** surgical robots and ***4)*** possibly patient-specific prostheses can be warranted. Each of these topics will be highlighted and briefly discussed in the following sections of the report.

3D PREOPERATIVE PLANNING

By obtaining full lower limb CT scans, preferably with 1 mm slices and an MRI of the knee, it is possible to create a virtual image of the bony and articular cartilage of the lower extremity of the knee.

On the 3D reconstructions through segmentation techniques, it is possible to obtain an exact measurement of prosthesis-articular cartilage

transition, axial/sagittal rotations and trochlear length. A virtual implantation of the patello-femoral prosthesis and patella button can be performed. Any conflict between articular cartilage junction and alignment can be predicted. From this, the most suitable position as well as the size of the prosthesis can be suggested for a particular patient (fig. 1).

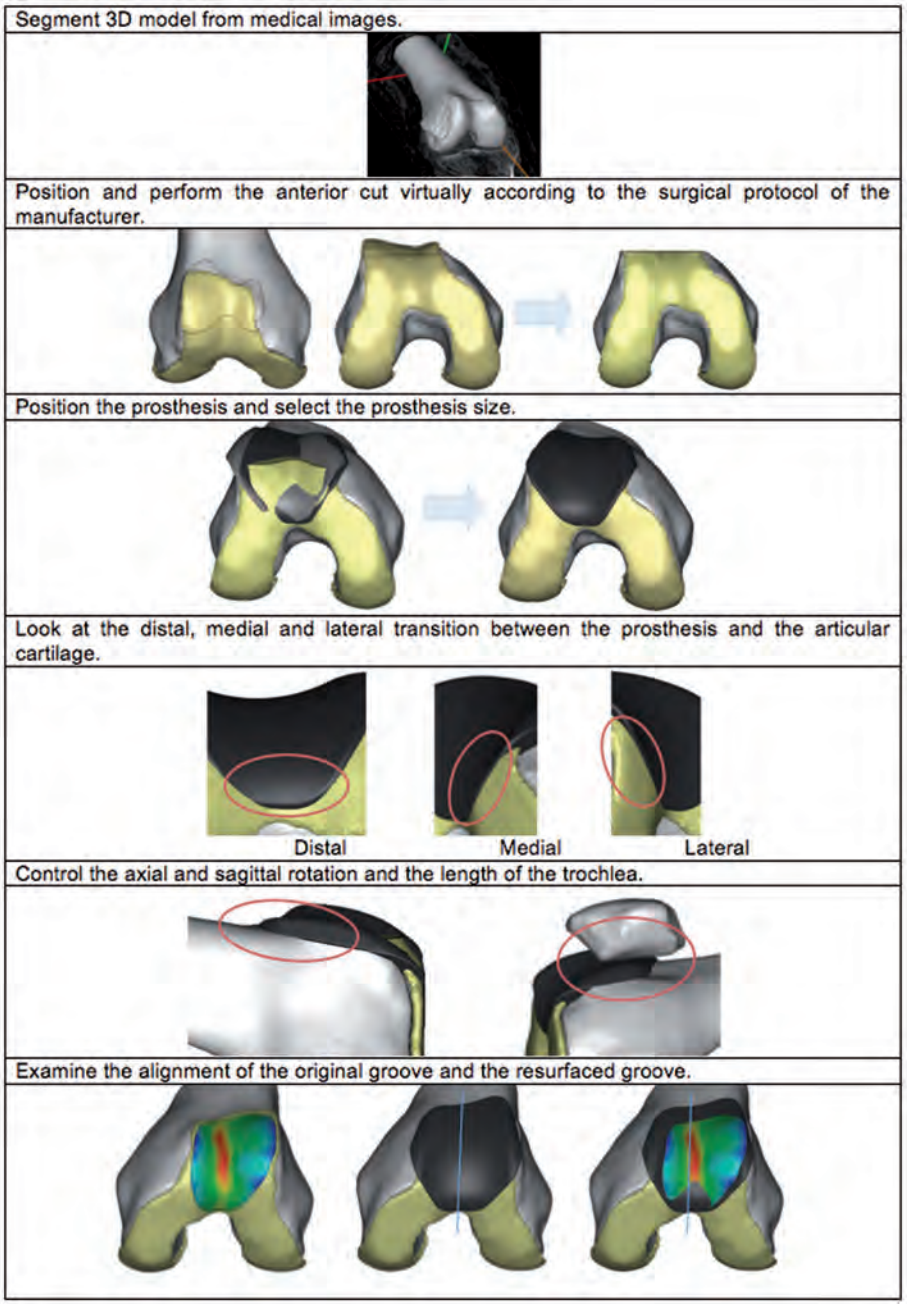

Fig. 1: Illustration of 3D preoperative planning of PFR via virtual implantation.

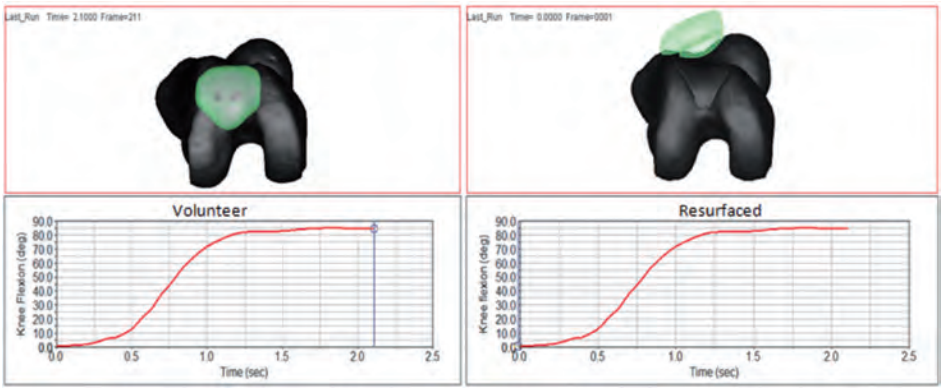

Fig. 2: The tracking pattern of the volunteer's knee and a resurfaced knee.

The kinematics of the virtually implanted prosthesis can then be observed and the effect of lateral release, MPFL reconstruction and tibial tubercle osteotomy can also be evaluated though computational methods. At present, this step is time consuming and associated with simplifications and estimations, and more research is necessary to streamline the process and validate model predictions. The proposed benefit of the computational method is the possibility of not only validating prosthesis suitability based on geometrical criteria, but also in terms of functional parameters such as tracking and joint pressures (fig. 2).

PATIENT-SPECIFIC INSTRUMENTATION

We prefer to have the most exact possible fit between the prosthesis and the patient's natural femur distal, medial and lateral. The rotation of the anterior cut in both the axial and sagittal plane has an effect on the prosthesis articular cartilage transition. The positive being that the medial and lateral fit will influence the trochlear groove alignment.

Once a satisfactory virtual implantation has been achieved, which is usually a compromise between a perfect prosthesis articular cartilage transition, a satisfactory axial and rotational alignment of the trochlear groove; a patient-specific instrumentation can be designed allowing for the precise positioning of the prosthesis. The patient-specific surgical tool can reproduce the position of the anterior cut made in the virtual space into the surgical environment by conforming precisely to the unique anatomy of the patient's femur. The anterior femoral cut is the only variable that we can control (fig. 3).

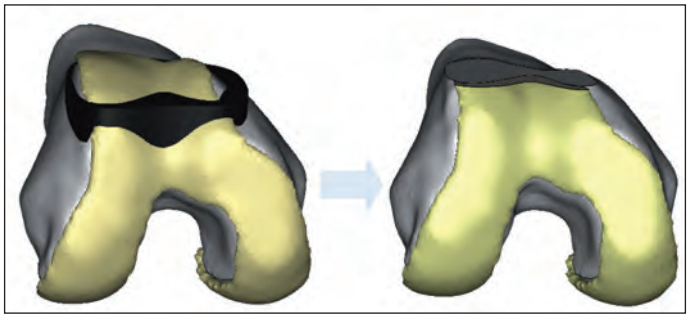

Fig. 3: The patient-specific surgical tool conforms to the patient's anatomy to reproduce the anterior cut made in the virtual space.

ROBOTIC BONE PREPARATION

Two types of robots are available; haptic and autonomous [2]. In haptic or tactile systems, the surgeon drives the cutting tool but the robot will prevent him to go off the pre-planned depth and position of the bone cuts. In the autonomous systems, the surgeon will do the approach, set up the robot and then stand back allowing the robot to do the bone cuts by itself.

With the haptic systems, a preoperative planning is done on 3D reconstructions from the CT and MRI. At the surgery, a surgeon would use the computer to determine the leg alignment and "morph" the joint surfaces in the same way as the CAD surgery. In contrast to CAD surgery, the bone cuts are now made under robotic control according to the preoperative planning (fig. 4).

However, even in these robotic systems a best fit is usually a compromise between a good prosthesis articular transition; and an acceptable axial and sagittal rotation of the prosthesis.

PATIENT-SPECIFIC PROSTHESIS

In a study where we virtually implanted 4 different commercially available prosthesis in a normal asymptomatic patellofemoral joint, it was evident that not one of these prosthesis restored the joint to normal [3]. All four prosthesis; the Avon™ Patellofemoral Arthroplasty (Stryker, Kalamazoo, Michigan, USA); the Competitor PFJ Oxinium (Smith & Nephew, Inc. Memphis, Tennessee, USA); the Vanguard™ Patellofemoral Replacement System (Biomet UK L^{td}, South Wales, UK); and the Kneetec, (Tornier, Fr) increased the medial A-P dimension, decreased the lateral A-P dimension and decreased the depth of the trochlea (fig. 5).

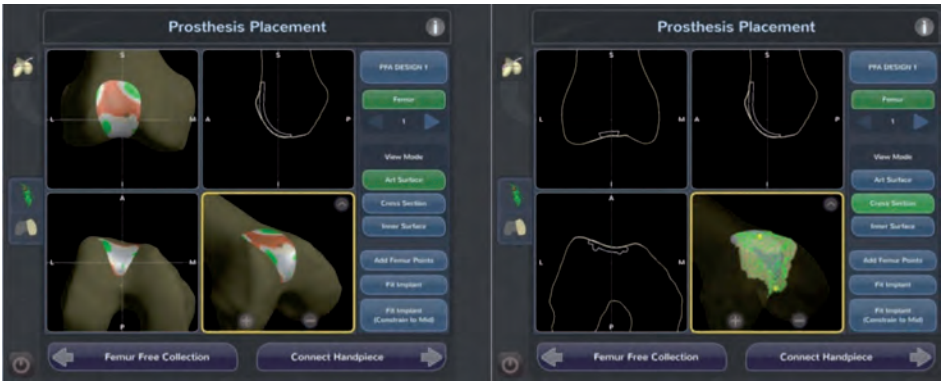

Fig. 4: Morphing the distal femur and planning the prosthesis position with the aid of a computer for implanting the prosthesis using a haptic robot (Navio PFSTM surgical system, Blue belt technologies, INC).

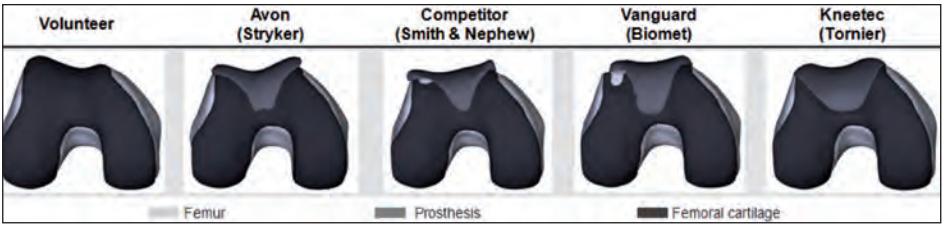

Fig. 5: Virtual implantation of 4 different commercial off the shelve prostheses implantation shows raised medial A-P dimensions relative to lateral A-P dimensions and decreased trochlear depth.

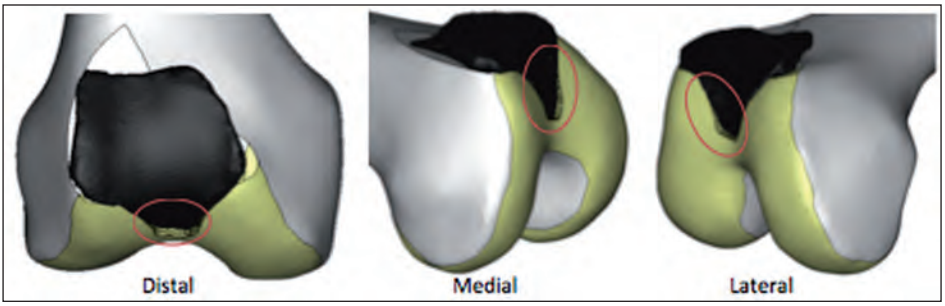

Fig. 6: An example of the misfit between a commercially available off the shelf prosthesis on the femur. The distal fit is compromised.

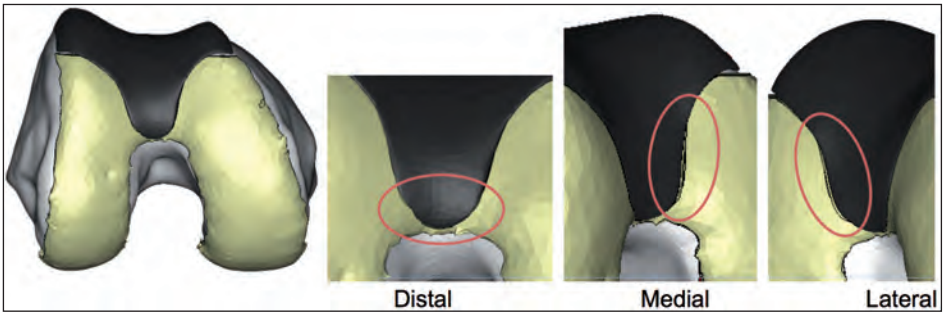

Fig. 7: Patient-specific prosthesis can ensure a smooth transition between the prosthesis and the patient's articular cartilage on distal, medial and lateral without compromising the trochlear groove alignment.

When doing preoperative planning, it becomes evident that in certain severe trochlea dysplasia cases it is impossible to fit any of the off the shelf commercially available prosthesis to the trochlea (fig. 6). In these cases the option is to consider a TKR rather than a PFR or to design a patient-specific prosthesis. Patient-specific prostheses need to be designed within predetermined parameters concerning things like; the trochlear angle; trochlear depth; medial-lateral dimension; and medial and lateral anterior-posterior dimensions (fig. 7).

At present the patient-specific prosthesis manufactured by CNC (computer numerical control) techniques are relatively slow and expensive because, the machines have to be specifically calibrated and set up to manufacture a single part. In future use it will be made of rapid or additive manufacturing, which are already in use in the aeronautical industry. As the costs come down, it would become an attractive option because these machines are particularly suited for making once off products (fig. 8).

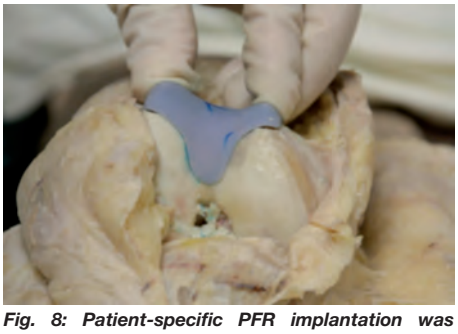

Fig. 8: Patient-specific PFR implantation was performed using patient-specific instrumentation. The prosthesis and the surgical instruments were manufactured using rapid prototyping (additive manufacturing).

CONCLUSION

PFR is a more of a less invasive option for treating isolated patellofemoral osteoarthritis than TKR [4]. At present, the outcomes of PFR have been less satisfactory than that of TKR and UKR. We do however believe that there is a place for PFR, taking into consideration that there is a group of patients with severe patellofemoral degeneration with normal tibiofemoral joints. We are optimistic that by incorporating new technologies like 3D preoperative planning, virtual implantation, robotics, patient specific instruments and in some cases patient specific prostheses, we should be able to improve the results. With these technologies, it is possible to preoperatively position and fit off the shelf prosthesis. Should it not be possible to properly fit an off the shelf prosthesis, a patient specific prosthesis can be designed. By doing this, we can expect to minimize complications and ensure constitutional or natural tracking of the patella. We are doing on-going research to define the parameters within which a patient specific prosthesis should be designed to fit into the patient's existing anatomy without creating abnormal kinematics or abnormal strain on the surrounding soft tissue structures.

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EVIDENCE OF TROCHLEAR DYSPLASIA IN PATELLOFEMORAL ARTHROPLASTY DESIGNS

M. SAFFARINI, P.G. NTAGIOPOULOS, G. DEMEY, B. LE NEGARET, D. DEJOUR

INTRODUCTION

In 1958, McKeever introduced patellar resurfacing implants [1-4], and in 1979, Blazina [5] and Lubinus [6] developed patellofemoral arthroplasty (PFA) as a less invasive alternative to total knee arthroplasty (TKA) for the treatment of isolated patellofemoral arthritis. Early PFA models produced poor clinical outcomes, due to improper patient selection, imprecise surgical technique, and flawed "trochlear resurfacing" designs that replaced the degenerative cartilage without correcting the underlying osseous deformities [7-11]. Later PFA models produced improved clinical outcomes, attributed to better patient selection, accurate surgical instrumentation, and enhanced 'trochlear cutting' designs that replaced the subchondral bone and corrected the depth and orientation of the trochlear groove [8-10, 12, 13, 11].

Both TKA and PFA are used to treat late isolated patellofemoral arthritis, and there remains considerable controversy as to which option is most suitable [8]. Failures of PFA implants are associated with two types of post-operative complications: (***i***) late complications due to the spread of arthritis to the tibiofemoral joint [11, 12, 8, 10, 14, 15], and (***ii***) early complications due to patellar mal-tracking, including painful instability, subluxation or dislocation [12, 8, 10, 14, 15]. Beyond the contributions of surgical technique, mal-tracking complications could also be related to implant design parameters. In particular, the authors question whether trochlear components of contemporary PFA implants exhibit geometric characteristics that would be consistent with the radiographic definition of dysplasia of the anatomic trochlea.

The standard method to assess the trochlea in patients is to measure the sulcus angle in "skyline" radiographs: with the knees in 45º of flexion as described by Merchant [18, 19] or with the knees in 30º of flexion as described by Brattström [20]. In healthy knees the mean sulcus angle is 138º in the "Merchant view" [18, 19, 21] or 142º in the 'Brattström view' [20], whereas in knees with trochlear dysplasia the sulcus angle exceeds 144º in the "Merchant view" [22] or 143º in the "Brattström view" [23]. Furthermore, the height of the lateral trochlear facet in healthy knees was reported in the radiographic study of Brattström [20] to be between 4.2 and 6.5mm (at 30º of flexion) and in the cadaver study of Shih *et al.* [24] to be 6.6 ± 1.8mm (at 0º of flexion). A recent study by Dejour *et al.* [25] revealed that some TKA designs exhibit characteristics of trochlear dysplasia and that in many models the sulcus angle exceeded those radiographic indicators of dysplasia by over 10º. Since many PFA

designs are derived from the trochlear portions of TKA models [12, 26, 11], we questioned whether some PFA models also exhibit characteristics of trochlear dysplasia. The design of the trochlear compartment is arguably more critical in PFA implants than in TKA implants, because 78% of patients with isolated patellofemoral arthritis also have pre-existent trochlear dysplasia and patellar mal-tracking [27] and therefore remain predisposed to patellofemoral complications [7].

The purpose of this study was to quantify the differences that exist between contemporary PFA trochlear implants with specific attention given to the sulcus angle and lateral facet height at various degrees of knee flexion. The hypothesis was that some of the designs would meet the radiographic definition of trochlear dysplasia and could explain some early complications. Because patellofemoral complications are usually caused by a combination of factors related to surgical technique and implant design, the authors did not attempt to correlate the findings with clinical results of the studied implants.

MATERIAL AND METHODS

The authors formed a sample of 5 trochlear components and identified and numbered each specimen by its laser marking to determine its manufacturer, model, serial number, size and side The specimens included the following models: Avon (Stryker, Mahwah, NJ), HLS KneeTec (Tornier SA, Montbonnot, France), Vanguard (Biomet Inc., Warsaw IN), PFC (DePuy Orthopaedics Inc., Warsaw, IN), NexGen (Zimmer Inc., Warsaw, IN) (**Table 1**). Specimens were chosen based on their sizes falling near the middlemost option of the available range.

The specimens were each scanned using a three-dimensional (3D) optical scanning machine (ATOS II, GOM mbH, Braunschweig, Germany). The coordinates of points scanned on each specimen were rendered into smooth surfaces using three-dimensional model reconstruction software (Rapid Form, 3D Systems Corp., South Carolina, USA), which enabled full manipulation and measurement using standard computer aided design software (Pro/Engineer, Parametric Technology Corporation, Massachusetts, USA).

The specimens were each oriented in a consistent coordinate system, defined with the "origin" at the tip of the most posterior fixation peg and: (***i***) the ML axis parallel to the frontal resection plane; (***ii***) the AP axis parallel to the distal resection plane (or to its posterior tangent in the case of a curved surface); (***iii***) the SI axis orthogonal to the distal resection plane (or to its posterior tangent in the case of a curved surface). The three reference planes of each specimen were hence defined: (***iv***) the ML and SI axes for the frontal plane; (***v***) the AP and SI axes for the sagittal plane; and (***vi***) the ML and

Table 1: List of the specimens measured and their principal dimensions.

Specimen	Manufacturer	Model	Size	Side	ML (mm)	AP (mm)	SI (mm)	Orientation of Trochlear Groove
1	Stryker	AvonTM	M	R	46.8	26.1	44.8	1.6°
2	Tornier	KneeTecTM	3	R	47.9	28.1	47.1	7.0°
3	Biomet	VanguardTM	M	L	46.3	38	53	2.0°
4	DePuy	PFC®	3	R	33.9	28.5	43.6	13.5°
5	Zimmer	NexGen®	3	R	45.1	24.5	42.9	7.3°

AP axes for the transverse plane. It is worth noting that for most specimens, the frontal resection plane is not parallel to the frontal plane, but inclined anteriorly by a few degrees.

The authors plotted the trochlear profiles of the specimens at different flexion angles following the same protocol published in a recent study on TKA specimens [25]. Each specimen was virtually rotated about its "origin" using Pro/Engineer around the ML axis by the following flexion angles: 0º, 15º, 30º and 45º. At each flexion angle, the most anterior point on the trochlea was marked, and the ML profile of the trochlea at that level was digitized (fig. 1).

All recorded coordinates were exported to spreadsheets using Microsoft® Excel (Microsoft Corp, Redmond, WA). To enable consistent geometric comparisons between all specimens, the coordinates of right-sided implants were mirrored to become superimposable with those of left-sided implants. The two-dimensional ML profiles of each prosthetic trochlea could therefore be superposed and compared with its origin at the intersection of (***i***) the midpoint between the medial and lateral margin of each specimen and (***ii***) the trochlear groove, or deepest point on the sulcus, of each profile.

The "sulcus angle" of each profile was calculated from the coordinates of the trochlear groove and those of the highest points of the medial and lateral facets (fig. 2). We used the following criteria from the literature as indicators of trochlear dysplasia: (***i***) sulcus

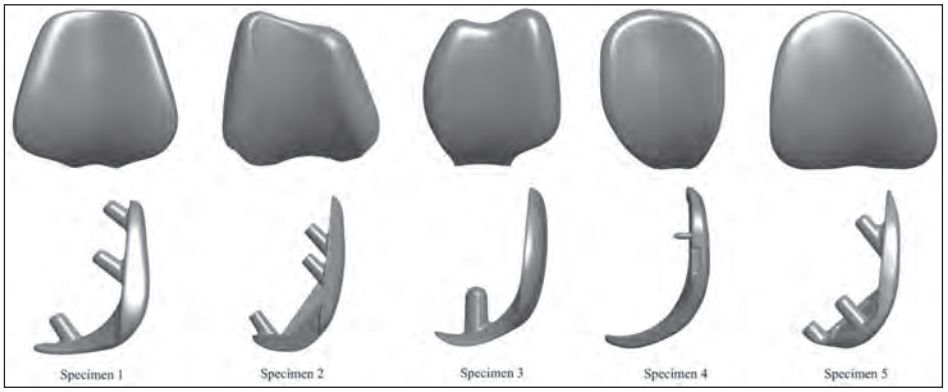

Fig. 1: Frontal and sagittal views of each specimen.

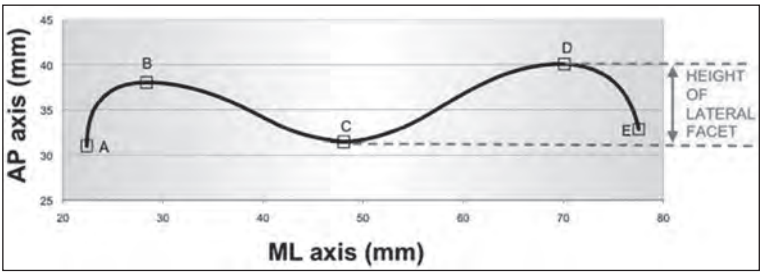

Fig. 2: Example of a two-dimensional trochlear profile at 30° of flexion. The letters indicate points of inflexion of the trochlear profile: A medial extremity; B peak of medial facet; C sulcus trough; D peak of lateral facet; E lateral extremity. The sulcus angle is BCD, the height of the lateral facet is the z-coordinate difference between points C and D.

angle above 144º in the "Merchant view" or above 143º in the "Brattström view" [20, 25, 22] and (***ii***) height of lateral trochlear facet less than 5mm [20, 25, 24]. The coordinates of the trochlear grooves were used to calculate a linear regression (using the method of least squares) in the frontal plane, and the trochlear groove orientation was calculated from the cosine of its gradient (fig. 3).

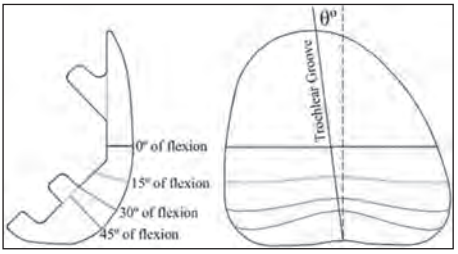

Fig. 3: Visual representation of trochlear profiles measured: (a) trochlear profiles viewed in the sagittal plane and (b) trochlear profiles viewed in the frontal plane and trochlear groove orientation.

RESULTS

The two-dimensional trochlear profiles at 30° of flexion for all 5 implants are presented to enable direct visual comparisons (fig. 4).

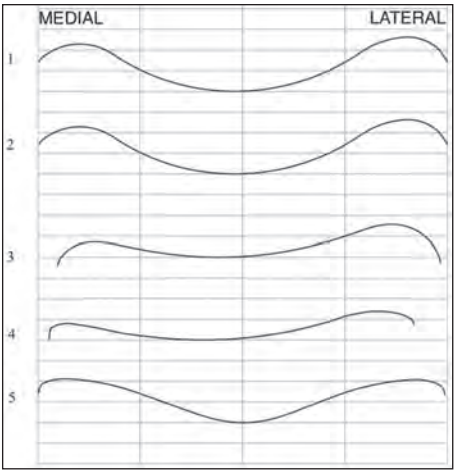

Fig. 4: Trochlear profiles of all specimens at 30° of flexion.

The sulcus angles of all trochlear profiles are presented graphically (fig. 5). Four specimens had a sulcus angle greater than 144° in the "Merchant view" (45° of flexion), and thus all but one specimen satisfied this first definition of trochlear dysplasia. Five specimens had a sulcus angle greater than 143° in the "Brattström view" (30° of flexion), and thus all specimens met the second definition of trochlear dysplasia. We observed different sulcus angle progressions in the range of flexion (0° to 45°): a considerable decrease (>10º) in 2 specimens, and a negligible decrease (<5º) in 3 specimens.

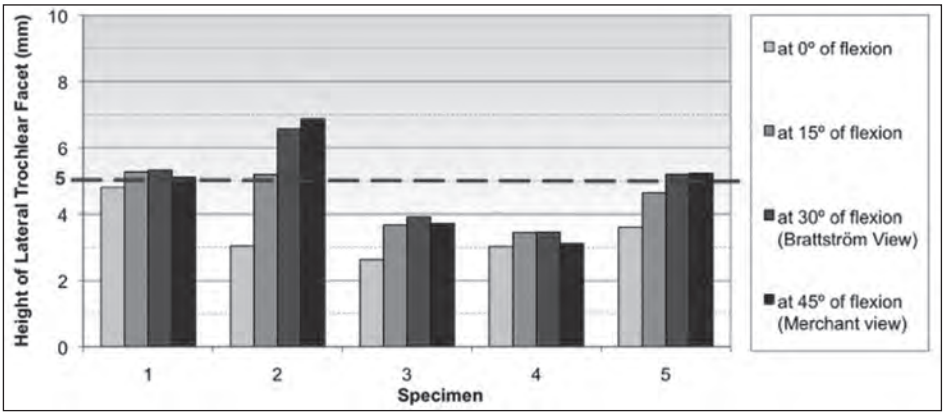

Fig. 5: Sulcus angle for all specimens at different flexion angles. The dashed red line represents the radiographic indicator of trochlear dysplasia (sulcus angle over 144º in the "Merchant view").

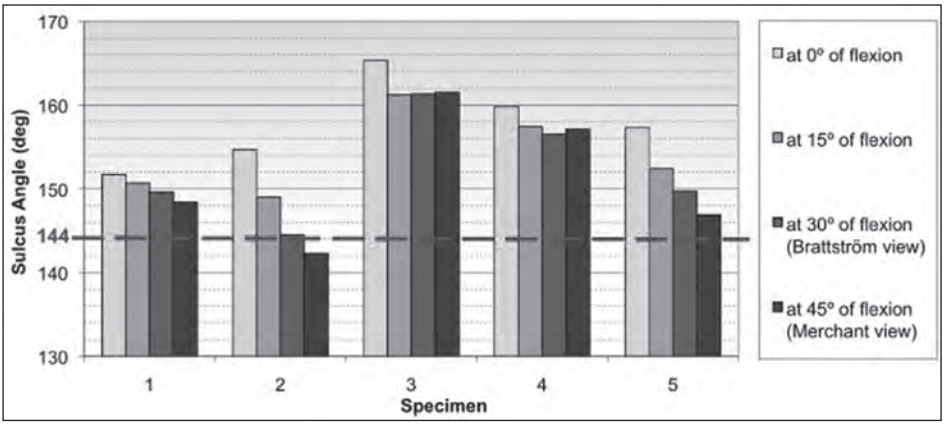

Fig. 6: Height of lateral trochlear facet for all specimens at different flexion angles. The dashed red line represents the radiographic indicator of trochlear dysplasia (lateral facet lower than 5mm in the "Brattström View").

The height of the lateral facet of all trochlear profiles is presented graphically (fig. 6). Visual comparison reveals that the lateral trochlear facet height is inversely proportional to the sulcus angle. Three specimens had a facet less than 5mm high through the entire range of early flexion (0° to 30°), and two specimens had a facet less than 5mm high beyond early flexion (30° to 45°).

When projected onto the frontal place, the trochlear groove was oriented laterally in all specimens within the range 1.6º to 13.5º (Table 1). The ratio of ML width to SI height at different flexion angles reveals that in most specimens the ML width is slightly greater at 15º and 30º of flexion than at 0º and 45º of flexion. Two specimens were relatively narrow (ML/SI < 1) while the other three specimens were relatively wide (ML/SI > 1).

DISCUSSION

This study revealed that contemporary PFA implants are not always designed with anatomic trochlear parameters, and some designs meet the radiologic criteria of trochlear dysplasia. Such components suppress intrinsic anatomic features that are essential for normal patello-femoral tracking. Failures of PFA implants are associated with two types of post-operative complications: (***i***) late complications due to the spread of arthritis to the tibiofemoral joint [36, 30, 13, 28, 24, 26], and (***ii***) early complications due to patellar mal-tracking, including painful instability, subluxation or dislocation [30, 13, 28, 24, 26]. Several studies reported improved clinical outcomes for recent PFA models [13, 27, 28, 30, 35, 36], and many authors attributed the reduced complication rates to enhanced trochlear component designs, together with better surgical techniques and instrumentation, that enabled restoration of normal patellar tracking [27, 28, 30, 35, 36]. The recent meta-analysis by Dy *et al.* [13] affirmed that complications of recent PFA models (14%) are fewer than those of earlier PFA models (39%) but still higher than those of TKA implants (7%), and that most PFA complications remain due to patellar instability and maltracking.

The surface geometry of the trochlear component is of great importance, in addition to accurate limb alignment and soft-tissue balancing, to restore patellar kinematics and to prevent patellar dislocation [28, 29]. In a normal knee, the patella is guided into the trochlear groove by the medial patellofemoral ligament in early flexion [30, 31], and by the lateral trochlear facet in later flexion [32, 33, 30]. In a knee with patellofemoral arthritis, the

soft tissues that stabilize the patella are often unbalanced, and the trochlea is usually dysplastic [27], thus the PFA trochlear component must provide a groove with normal anatomic depth to guide the patella, and must realign the extensor mechanism to ensure normal patellar tracking.

Of the five implants measured, four had a sulcus angle greater than 144° in the "Merchant view" and all 5 specimens had a sulcus angle greater than 143° in the "Brattström view". In two of the specimens the sulcus angle exceeded these radiographic indicators of trochlear dysplasia by more than 10º. A high sulcus angle indicates a shallow or dysplastic trochlea, observed in the majority of patients suffering from patellofemoral disorders [33]. Trochlear components with high sulcus angles require a specific and adapted surgical technique including ligament balancing and extensor mechanism realignment according to the TT-TG value to prevent any further patellar maltracking in early flexion.

Of the five implants measured, three specimens had a facet less than 5mm high through the entire range of early flexion (0° to 30°), and two specimens had a facet less than 5mm high beyond early flexion (30° to 45°). The lateral facet is essential to align the patella within the trochlea during knee flexion, and to prevent lateral subluxation and tilt [34, 35]. In a radiographic study of 200 normal knees, Brattström reported the range of lateral facet height to be 4.2 to 6.5mm (at 30º of flexion) [20]. In a more recent cadaver study of 33 femora, Shih *et al*. reported the mean height of the lateral facet to be 6.6 ± 1.8mm (at 0º of flexion) [24]. A low facet would predispose to lateral patellar dislocation, while an elevated facet could exacerbate tension in the lateral patellar retinaculum, and potentially lead to excessive patellofemoral contact pressures and impingement [34].

In all specimens, the trochlear groove was oriented laterally (range 1.6º to 13.5º). There is general consensus that the trochlear groove is bilinear, with different orientation in its proximal and distal portions [37-40], but there are debates on whether its orientation is lateral [41], parallel [42, 43], or medial [44, 45] to the femoral anatomical axis. The position of the trochlear groove is fundamental as it influences the final alignment for correction of the TT-TG. The closer the position of the prosthetic groove to normal anatomy, the better the correction of the alignment, and the less the surgeon needs to deal with implant orientation.

Two of the specimens appeared relatively narrow, while the other three specimens were relatively wide.

With a narrow implant, some of the native medial and lateral facets are preserved, which is an advantage as there is less bone resection. However, implant positioning is not adjustable after cuts, and in case of high-grade trochlear dysplasia, where the entire trochlea is abnormal, the cut and implant would not fully correct the abnormality [16, 15]. With wider implants, the required bone resection is greater, but the surgeon has more freedom to move the trochlear groove medially or laterally as necessary to correct alignment [7, 8, 10, 12]. Ideally, a trochlear component should extend far enough distally to allow proper coverage of the diseased trochlea and facilitate proper implant positioning and orientation, without encroaching into the intercondylar notch [15], as this could lead to impingement against the anterior cruciate ligament and lead to ligament damage and lack of extension.

The present study invokes a discussion on the common classification of PFA implants. Numerous authors distinguished implants as first – or second – "generation" based on the year they were released on the market [16, 46, 8, 12, 11]. First generation implants included the Lubinus, Blazina, Richards Mod II and III systems, while second generation implants included the Avon, Autocentric, and LCS systems. We find it more appropriate to classify

implant by design rather than by "generation": (***i***) "trochlear cutting" PFA, which require complete removal of the native trochlea, and (***ii***) "trochlear resurfacing" PFA, where the implant replaces the worn cartilage without altering the shape of the native trochlea. Trochlear cutting implants permit the surgeon to alter the position of the trochlear groove and thereby correct the TT-TG alignment. Trochlear resurfacing implants do not permit such realignment unless the operative technique involves distal realignment like a TT osteotomy. Dejour and Allain [27] demonstrated that implant survival was higher for trochlear cutting imlplants and trochlear resurfacing implants combined with distal realignment, compared to trochlear resurfacing implants without distal realignment.

The strengths of this study were that it featured five designs that are in clinical use, and that the measurement techniques were consistent and reproducible. In addition, the "scale factor" was minimized by studying specimens from the middle of the size range and by referring to a non-dimensional variable of sulcus angle. The main weaknesses of the study were the consideration of the trochlear component and not the patellar component, and the focus on static design features rather than dynamic implant performance.

CONCLUSION

The current study presented a quantitative comparison of crucial design parameters of contemporary PFA implants and revealed that some trochlear components exhibit characteristics of dysplasia. Such components suppress essential anatomic for normal patellofemoral tracking. We therefore advise surgeons to use implants with a deep trochlear sulcus ("trochlear-cutting") particularly in patients with history of patellofemoral disorders, and to adapt their surgical techniques and extensor mechanism if the selected implant has a shallow trochlear sulcus ("trochlear-resurfacing").

ABSTRACT

Purpose: The design of the trochlear compartment is crucial in patellofemoral arthroplasty (PFA), because 78% of patients with isolated patellofemoral arthritis present concomitant trochlear dysplasia with patellar mal-tracking, and therefore remain predisposed to post-operative patellar subluxation and dislocation. The study investigated whether current PFA implants are designed with anatomic trochlear parameters such as the sulcus angle, lateral facet height and groove orientation.

Methods: Five trochlear components of commercially available PFA implants were scanned and the generated 3D surfaces were measured using engineering design software. The mediolateral trochlear profiles were plotted at various flexion angles (0°, 15°, 30° and 45°) to deduce the following variables: sulcus angle, height of lateral facet and trochlear groove orientation.

Results: Four specimens had sulcus angle greater than 144° in the 45° of flexion, and all five specimens had sulcus angle greater than 143° in 30° of flexion. Three specimens had a facet less than 5mm high through the entire range of early flexion (0° to 30°), and two specimens had a facet less than 5mm high beyond early flexion (30° to 45°). The trochlear groove was oriented laterally in all specimens (range 1.6º to 13.5º).

Conclusions: Current PFA trochlear components are not always designed with anatomic parameters and some models exhibit characteristics of trochlear dysplasia. Surgeons are therefore advised to implant components with a deep sulcus, particularly in patients with history of patellofemoral disorders, and to adapt the surgical technique and extensor mechanism if the component implanted has a shallow sulcus, to ensure normal patellar tracking.

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ANATOMY, KINEMATICS AN KNEE PROSTHESES; 3D VARIATIONS IN KNEE ANATOMY?

J. BELLEMANS, J. OOSTERBOSCH, J. TRUIJEN

Today there is an increasing awareness amongst knee surgeons about the individual variability in anatomical shape of the knee and natural alignment of the leg. Nevertheless we continue to treat our patients on a relatively uniform basis, using a limited set of standard component sizes and shapes, and a surgical technique aiming at zero degree mechanical limb alignment in all of our cases.

This dogmatic approach has nevertheless been relatively successful in the past, with acceptable results in terms of pain reduction and restoration of functionality. Despite this, many patients with artificial knee replacement however continue to experience functional limitations and discomfort in the operated joint, especially when compared to healthy, non-operated peers of the same age.

The inability to restore the individual's anatomic configuration with our current prosthetic designs and surgical techniques may be an important factor in this. The quest towards individualized surgical strategies and implants in order to restore the patients individual pre-diseased profile or status is therefore an attractive path onto which knee surgeons and implant designers have recently embarked. The recent progress in understanding the effect of certain factors such as gender, morphotype, and native alignment have lead to a better understanding of the constituents that determine the individual profile of the patient's knee, and these are therefore the basis towards a potentially more successful artificial reconstruction of the knee joint.

In this chapter we will focus on each of these factors, starting with the patient's pre-diseased alignment.

CONSTITUTIONAL ALIGNMENT

The main purpose of either partial or total knee arthroplasty has always been to replace the eroded cartilage and bone by an artificial implant, usually out of metal and plastic and which compensates for the erosion or damage. When doing so, restoration of neutral mechanical alignment has traditionally been considered as the most important factor with respect to the durability of the implant. When neutral mechanical alignment is restored, the mechanical axis of the leg passes through the centre of the knee, which leads to an even mediolateral load distribution and a minimized risk for implant wear and component loosening. For this reason, several techniques to obtain intraoperative restoration of mechanical alignment have been used in the past, usually by referencing from intramedullary or extramedullary alignment rods, or using more sophisticated computerized navigation methods.

Recently however, the concept of anatomical restoration has gained interest amongst knee surgeons. In this philosophy the natural anatomy of the knee is restored, by using patient specific implants that selectively or completely resurface the eroded or damaged parts of the knee back to its original anatomic contours. This approach would not necessarily restore the alignment to neutral, but rather to the natural alignment of the knee before the disease or damage occurred.

A number of patients may indeed exist for whom neutral mechanical alignment is abnormal. Patients with so called "constitutional varus" knees have since their end of growth always had varus alignment. Restoring neutral alignment in these cases would be abnormal for them, and in fact would almost per definition require some degree of medial soft tissue release (fig. 1).

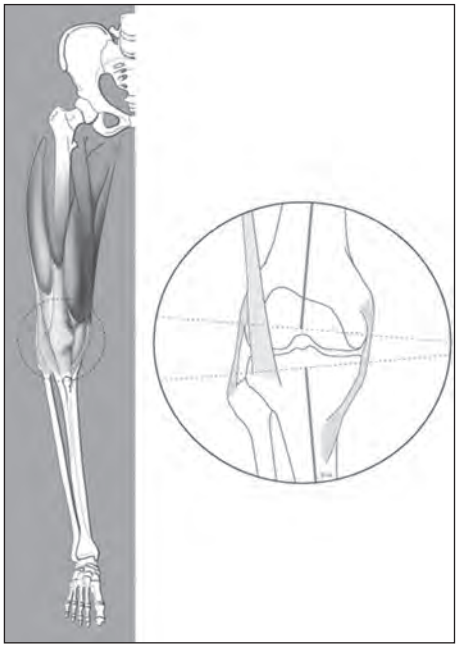

Fig. 1: Patients with constitutional varus knees have varus alignment since they reached skeletal maturity. Restoring neutral alignment in these cases may in fact be abnormal and undesirable, and would almost per definition require some degree of medial soft tissue release [4].

At the same time, anatomic restoration of these knees would lead to a mechanical alignment in varus, which could jeopardize the long term survivorship of the procedure.

The surgeon is therefore confronted with a strategic dilemma in these patients with constitutional varus; that is either to opt for neutral mechanical alignment restoration while realizing that this is abnormal for that specific patient, or to opt for anatomic restoration and accepting varus mechanical alignment. Unfortunately, until recently no data were available on the question whether constitutional varus really exists in the normal population, and if so in what percentage of healthy individuals it occurs. Also it was unclear how these patients could be recognized during surgery. We therefore performed an interesting study in order to investigate this [4].

A cohort of 250 asymptomatic adult volunteers between 20 and 27 years old was recruited, and all of them underwent full leg standing digital radiography on which 19 different alignment parameters were analyzed. The incidence of constitutional varus alignment was determined and contributing factors were analyzed using multivariant prediction models.

Interestingly, as high as 32% of males and 17% of females had constitutional varus knees with a natural mechanical alignment $\geq 3°$ varus [4]. Constitutional varus was associated with increased sports activity during growth, increased femoral varus bowing, an increased femoral neck-shaft angle, and an increased femoral anatomic-mechanical angle.

The average mechanical hip and knee angle (HKA) in the male knees was 1.9° varus (SD 2.1) and in the female knees it was 0.8° varus (SD 2.4) (fig. 2). One hundred sixty five (66%) of the male knees and 200 (80%) of the female knees had an HKA between -3° and +3°. Five (2%) of the male and 7 (2.8%) of the female knees had an HKA $\geq +3°$.

The number of patients with constitutional varus in our study (32% of males, 17% of females) may at first sight seem relatively high.

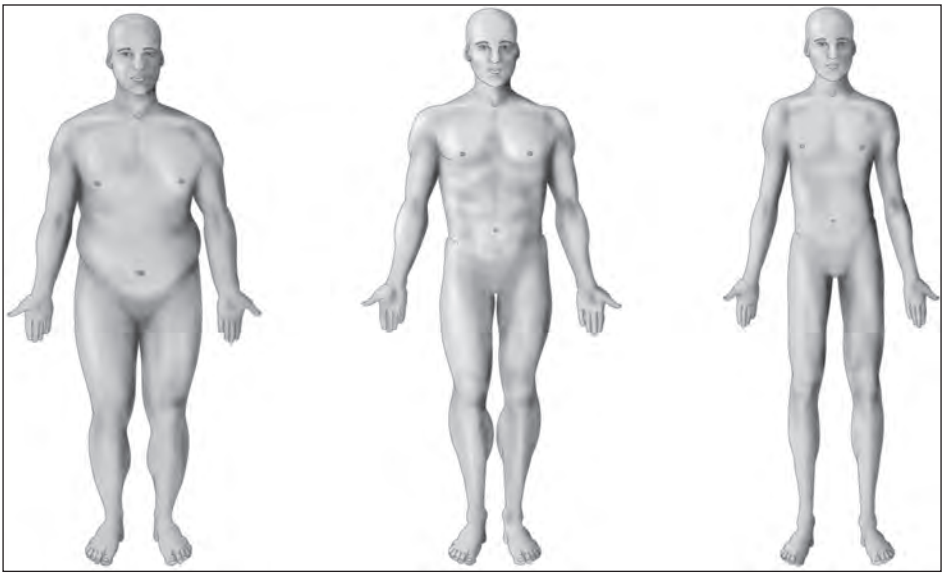

Fig. 2: Together with gender, the patient's morphotype is another important predictor of the shape of the knee. The three basic morphotypes are endomorph (left), mesomorph (middle), and ectomorph (right) [3].

Indeed, although many authors have studied normal lower leg alignment in humans before, this finding has been unrecognized so far. Some of the reasons for this are the fact that many classic alignment studies have been flawed with a number of shortcomings, such as a limited number of participants, a large variability in the subjects' age, recruitment in a hospital setting, lack of stratification, and selection bias of the subjects.

The association of constitutional varus alignment with increased physical activity during growth has been raised by other authors before. Witvrouw *et al.* have noted that intense sports activity during growth leads to the development of varus knees, and this phenomenon occurs especially towards the end of the growth spurt [30].

We believe that such is the consequence of Hueter-Volkmann's law, which states that growth at the physes is retarded by increased compression, whereas reduced loading accelerates growth [25, 28, 29]. The increased loads caused by the adduction moment on the knee during ambulation and physical activity leads to the development of varus alignment secondary to delayed growth on the medial side and accelerated growth on the lateral physes. Cooke and Lavernia have in the past already alluded to this theory in a biomechanical study on the etiology of pediatric tibia vara [12].

The observations from our study have proven that an important variability in natural alignment exists amongst individuals. One should therefore question the dogma that zero degree mechanical alignment should be the goal in every patient undergoing TKA.

Restoring the alignment to neutral in patients with constitutional varus would indeed be abnormal and in fact unnatural for them, since it would implicate an overcorrection towards their natural situation in which they had spent their life since skeletal maturity.

A strategy where the natural alignment of the patient is determined and subsequently reproduced, seems therefore much more logical.

GENDER AND MORPHOTYPE

The ongoing debate whether gender differences in the dimensions of the knee should impact the design of TKA components is still unsolved. Consensus exists however on the fact that the shape of the knee is – on average – different for men and women [10, 11, 12, 13, 14, 15, 20]. One of the confounding observations is that within men and women large differences exist, with some women demonstrating a "male" type geometry and *vice versa*, some males demonstrating a "female" shaped anatomy. In a recent study we explained this phenomenon by demonstrating that not only gender, but also the patient's morphotype determines the shape of the distal femur and proximal tibia, and that this factor should therefore be taken into account when designing gender specific TKA implants.

In our study 1000 consecutive patients undergoing TKA were analyzed and stratified into three groups based upon their anatomic constitution; endomorph, ectomorph, or mesomorph [17, 18, 25].

Endomorphs are characterized as having a round body shape with short and taper extremities, mesomorphs have a muscular and V shaped body constitution, whereas ectomorphs have a slim and tall morphology with long arms and legs (fig. 2).

The purpose of our study was thus to investigate the influence of morphotype as well as gender on the actual dimensions of the distal femur and proximal tibia in the population undergoing TKA [3].

Of the 250 smallest knees in our study 98% were female, whereas 81% of the 250 largest knees were male. In the group with intermediate size knees, female knees were significantly more narrow than male knees. Patients with smaller knees (predominantly female) demonstrated large variability between narrow and wide mediolateral dimensions, irrespective of gender. The same was true for larger knees (predominantly male).

This variability within gender could partially be explained by morphotypic variation. Patients with short and wide morphotype (endomorph) had, irrespective of gender, wider knees, while patients with long and narrow morphotype (ectomorph) had more narrow knees.

Our study therefore indicated that both morphotype and gender are significant determinants with respect to the geometry of the distal femur and proximal tibia.

For the distal femoral geometry, gender was a stronger predictor than morphotype, and contributed 48% to the variability in distal femoral aspect ratio, compared to 17% for morphotype. For the proximal tibial geometry, morphotype was the strongest predictor. The influence was however less pronounced than for the distal femur, with morphotype only contributing 4% to the variability in the tibial aspect ratio versus 2% by the patient's gender. In other words, although distal femoral geometry seemed to be influenced in an important way by gender and morphotype of the patient, such was also true for the proximal tibia, but to a much lesser extent [3].

The fact that morphotype is a predictive variable to the actual shape of the knee is not so surprising. Researchers have recognized the close interrelationship between morphotype and physical characteristics for a long time, which has lead to many studies on the influence of morphotype on physical skills and performance [2, 8, 21, 26]. The morphotype concept was initially introduced by Sheldon in the 1940s, and later refined by Carter and Heath, who defined the three basic somatotypes (endo-, meso-, and ectomorph) based upon the study of thousands photographed bodies of men from front view, side view and back view [17, 18, 25]. In this theory the three somatotypes form a basic classification under which any person can be subdivided depending on his skeletal frame and body composition. Although the morphotype concept has received many criticism in the past for its simplicity and (mis) use by anthropologists and behavioural scientists to correlate certain morphotypes with certain psychological characteristics, there is

much less discussion on its validity with respect to the study of physical characteristics [2, 8, 21, 26]. Our work in a certain way confirms this by demonstrating the correlation of morphotype with the geometric shape of knee.

Our study has also confirmed the influence of gender on the shape of the knee, and therefore seems to support the theoretical concept of gender specific implant geometry, at least for the intermediate sizes [1, 6, 7, 10, 19, 22, 23]. Whether such implants could lead to improved clinical results, is however another matter and until today not proven [5, 11, 13]. In view of this it is interesting to note that our work also demonstrated that, within gender, indeed significant variability exists in mediolateral versus anteroposterior dimensions, which is explained by the influence of morphotype.

Patients with smaller knees (predominantly female) demonstrated large variability between narrow and wide mediolateral dimensions for any given anteroposterior size, irrespective of gender. The same was also true for larger knees (predominantly male). It could therefore make sense to consider variable mediolateral implant dimensions to span this divergence in patient's morphology, even within the same gender. Again, it remains to be seen whether such could lead to a better clinical outcome, but at least we believe that the scientific basis exists to support the theoretical rationale of such concept.

CONCLUSION

In practice the above would suggest the necessity for a highly individualized implant shape and surgical strategy. Recent technological improvements allowing additive manufacturing, digital printing, and accurate component placement according to the patients native pre-diseased status, makes this option closer to reality for surgeons than ever before. Again, it remains to be proven that such individualized approach indeed would lead to better clinical results, but at least a strong theoretical basis thereto exists.

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SOFT TISSUES AND TKA

M. BONNIN, T. VAN HOOF, A. DE KOK, M. VERSTRAETE, C. VAN DER STRATEN, T. AÏT SI SELMI AND J. VICTOR

SOFT-TISSUE IMPINGEMENT AFTER TKA: WHAT IS IT?

In TKAs', residual pain and poor functional results can be due to soft tissues impingements with the prosthetic components [5, 8, 9]. Several structures can be involved such as the Popliteus Tendon (PT), the Patellar tendon (PaT), the Quadriceps tendon (QT) the Medial Collateral Ligament (MCL), the Patellofemoral Ligaments and generally speaking all the knee joint capsule. Very few reports are available in the literature about that topic and they focus mostly on the relationships between PT and the lateral condyle [1, 2, 7].

Soft-tissue impingement are mainly due to a prosthetic overhang [3, 4, 6, 8] but they can also be observed after apparently well-sized implants, without real prosthetic overhang [7]. In a previous work we reported better pain scores, better functional scores and better ROM in patients with "undersized components", where the implants did not cover the all bone cut area, than in patients with "normosized implants", where bone implant fit was apparently optimal [3].

In our hypothesis soft tissues-implant impingement is not only due to prosthetic overhang (technical mistake) but also to design factors – the non-anatomic shape of knee components – and therefore may occur in apparently well sized implants.

THE POPLITEUS TENDON IN TKA: WHY A THEORETICALLY "NORMOSIZED" TIBIAL PLATEAU IS IN FACT "OVERSIZED"?

In a normal knee the Popliteus Tendon (PT) is in close contact with the posterolateral aspect of the lateral tibial plateau, which can easily be visualized during anatomic dissections or during MRI (fig. 1). At the jointline level, the PT crosses the Lateral Meniscus through the Politeus Hiatus and is stabilized by the popliteomeniscal ligament. During TKA, the surgeon aims at preserving the native thickness of the tibial plateau, as measured on the healthy side – generally at the top of the convexity of the lateral tibial plateau. However, prosthetic tibial components do not reproduce the shape of the posterolateral tibial plateau – concave rather than convex – and this can lead to a Popliteus Tendon impingement with the tibial plateau (fig. 2). The potential tendon instability, due to the lateral meniscectomy and the resection of the popliteomenical ligaments, probably increases also the risk of impingement.

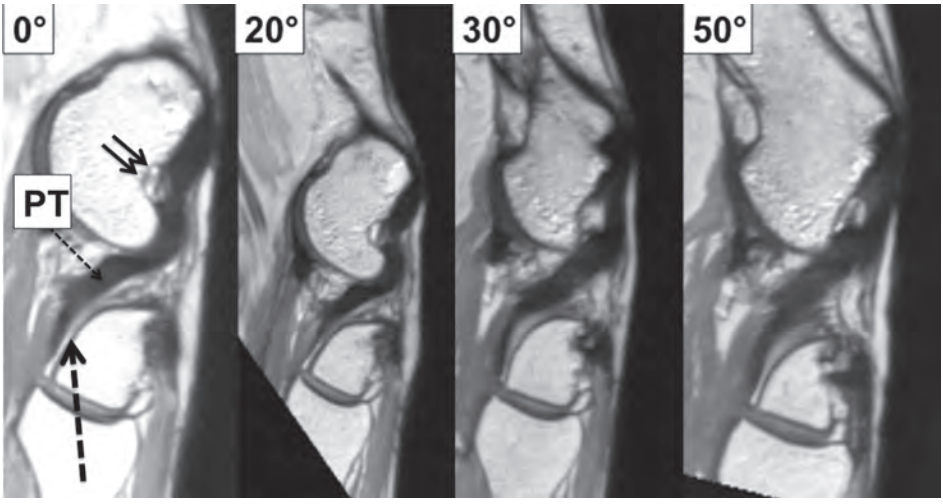

Fig. 1: These images were obtained with a 7 Tesla MRI from 0° to 50° of flexion. The slices are oblique and aligned with the Popliteus tendon (PT) from its insertion at the level of the lateral epicondyle (double black arrow) down to its contact with the lateral tibial plateau. In the posterolateral area, the PT is in close contact with the lateral plateau through a cartilaginous surface (dotted black arrow).

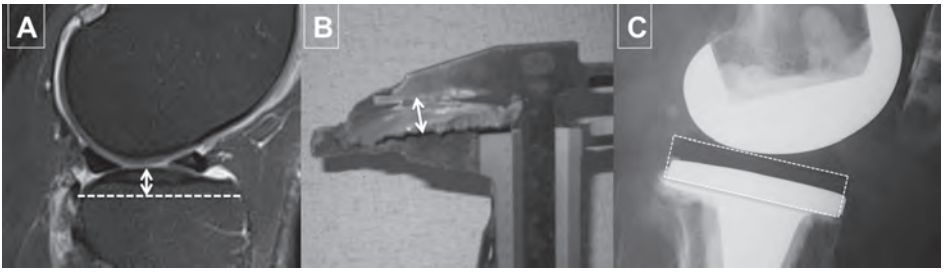

Fig. 2: In the sagittal plane, the shape of the normal lateral plateau is convex (A from MRI). During TKA, the level of resection is generally referenced to the lateral plateau, with a measurement at the top of the convexity (B). The prosthetic tibial plateau is more or less a parallelepiped in the sagittal plane (C) and therefore the posterolateral area has an increased volume compared with the native tibia.

HOW IMAGING THE SOFT-TISSUES AROUND A TKA? AN IN VITRO STUDY

A precise imaging of the soft tissues tracking around TKAs' during knee flexion would be very valuable but it is challenging due to their Chromium-Cobalt alloy structure. Magnetic Resonance Imaging (MRI) does not provides good quality images in TKA, CT-scan analyzes only components orientation, bone quality, bone losses and components loosening. Ultrasonography can also be used with TKA for clinical purposes but it is hardly used for precise anatomic investigations. Arthroscopy can also be used but only in selected indications.

The purpose of this study was to analyse *In Vitro* the relationships between soft tissues and TKA with commercially available implants.

Protocol

Between January 2013 and July 2014 we analyzed the behavior of the soft tissues during knee flexion on eight cadaver knees before and after TKA implantation. The ethical committee of our institution approved this investigation. Cadavers in this study were donated according to standard procedure. None of these knees had previous surgery as far as we can judge from the skin aspect as no clinical information was delivered from these cadavers. We investigated the tracking of five specific anatomic structures from full extension to maximum flexion, before and after TKA implantation: The Popliteus Tendon (PT), the Lateral Collateral Ligament (LCL), the Iliotibial band (ITB), the Medial Collateral Ligament (MCL), the Quadriceps Tendon (QT) and the Patellar tendon (PT). The implanted prosthesis was a copy of the HLS-KneeTech® (Tornier SA, Montbonnot, France) provided by the manufacturer and obtained from additive manufacturing technology: Fused Deposition Modeling, FDM®, with a Stratasys Dimension Elite™ (Eden Prairie, MN USA) using a non radio-opaque and non-magnetic polymer (Acrylonitrile butadiene styrene).

The knee was scanned from full extension to full flexion by 20° increments, before and after implantation of the TKA. Four knees were scanned with a 5 Tesla MRI (Siemens Sensation, Munich, Germany) and four knee with CT-scan after injection of baryum sulfate into the soft-tissues. PT and LCL were approached via a longitudinal lateral incision with the knee at 90° flexion. Ilio-tibial band was then incised longitudinally and LCL was identified, between the head of the fibula and the lateral epicondyle. After meticulous dissection, the PT was palpated and progressively visualized crossing the LCL at its deep face. QT and PT were approached from a medial parapatellar incision after patellar eversion and fat pad excision. MCL was approached from the anterior skin incision after subcutaneous dissection. The superficial fibers of the MCL were dissected from their epicondylar insertion to their distal tibial insertion. A mixture of glycerol (60%) and Baryum sulfate (40%) was prepared and injected meticulously in the different tendons and ligaments. After application of the contrast medium, a meticulous multilayer closer was conducted with separate Vicryl® 2-0 sutures (Ethicon, Somerville, NJ, USA). After local preparation all specimens were scanned with an identical protocol using a helical scanner (Siemens Sensation, Munich, Germany).

Surgical technique for TKA implantation

HLS-KneeTech® is a postero-stabilized TKA, with eight sizes for the tibial component and ten sizes for the femoral component, with standard and narrow components for the sizes 3 to 5. Implantation was done through a medial parapatellar approach and the patella was everted during the procedure but was not resurfaced. We used the standard conventional instrumentation obtained from Tornier SA. An orthogonal tibial cut was done at the first step, following an intra and an extra medullar guide. A 9mm resection was measured from the palpator. On the femur, the posterior cut was externally rotated in order to obtain a balanced knee in flexion. The distal femoral cut followed the intramedullary rod with a 7° valgus alignment. Stability and range of motion (ROM) were tested with the dedicated trial components and then, the implanted were cemented in one step. We did not use conventional surgical cement, with contains baryum sulfate, but Polyester (Polyester Demaere, Brussel, Belgium). After TKA implantation the lower limb was scanned in supine position from femoral head to ankle joint so that we could control the alignment.

Sizing of the implants

On the femur anteriorposterior (AP) measurement was done with a caliper in order to avoid anterior notching of the anterior cortex. The mediolateral dimension (ML) was carefully adjusted both on the femur and the tibia. We successively implanted ***1)*** Normosized TKA: (the contours of the implants fit exactly with the contours of the bony section), ***2)*** Undersized

TKA (the contours of the implants is always more than 2mm inside the bony contour) and ***3)*** Oversized TKA (the TKA overhangs more than 2mm from the bony contours).

Analysis of DICOM images

DICOM images were analyzed with OsiriX® software, with 3D multiplanar reconstructions. From these raw images segmentation was done with Mimics® software (Materialize®, Leuven, Belgium) in order to obtain three-dimensional images. To improve the quality of the implants visualization, the Stereo Litography files (STL) of the implants were obtained from the manufacturer, so that we can match with the raw DICOM images (fig. 3).

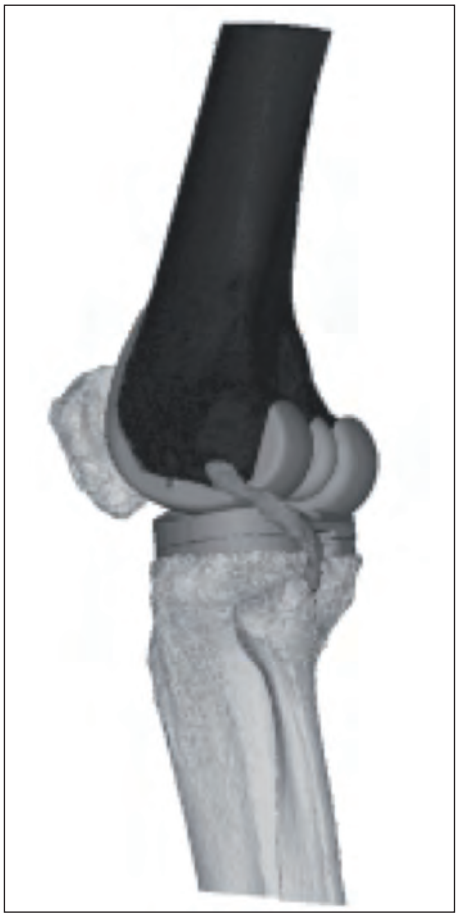

Fig. 3: Three-dimensional reconstruction of the knee, obtained from DICOM images after implantation of the TKA. In this specimen, the prosthesis was "normosized". The PT crosses the posterolateral corner of the plateaus. Reconstructions were made with Mimics® software (Materialize®) with a fusion of the STL files of the implant.

IMAGING OF THE PT IN THE NORMAL KNEE: THE "FUNCTIONAL" TIBIAL PLATEAU AND THE "ANATOMIC" TIBIAL PLATEAU

In a normal knee, the PT crosses the postero-superior surface of the tibial plateau, with a maximum overlapping of 5.5mm (75mm^2), observed while the knee is fully extended (fig. 4 and 5). This overlap decreases from 0° to 90° of flexion. In deep flexion, the PT remains distant from tibial plateau.

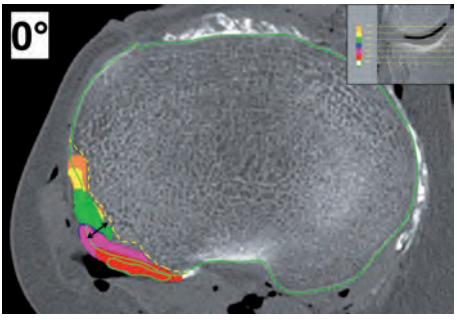

Fig. 4: This axial slice represents the standard tibial cut made at 9mm from the top of the lateral plateau. The contours of the tibia are circled in green. The positions of the popliteus tendon on each CT slice, from 9mm (circled in green) to 5mm above the joint line level (JL) (orange) are projected on this slice (i.e., 7.5mm distal to JL in red, 5mm distal to JL in purple, 2.5mm in blue, JL level in green and 2.5mm above JL in yellow). The PT overlaps the reference cut in all the posterolateral area. The maximum overlap zone in this specimen was 7mm (black arrow). To avoid impingement, the prothetic plateau should no overhang from the yellow dotted line, which mark the limit of the "functional" tibial plateau.

Consequently, if the contour of the tibial component matches exactly the bony contour of the tibial cut – theoretical optimal sizing – the PT impinges on the polyethylene on a significant area. Ideally the tibial plateau should be undersized by 5 to 6mm in the posterolateral corner of the tibia but this is difficult to satisfy this goal with symetrical implants and frequently the surgeon must accept a sizing compromise (undersizing the medial tibial plateau) or a position compromise (internal rotation of the tibial baseplate).

This study demonstrate that optimal tibial component design should be adapted to the dimensions of this "functional" tibial plateau (bone cut area without the PT contact area) rather than to the raw bony contours. New morphometric investigations should therefore be conducted in order to redefine these dimensions.

IMAGING OF THE SOFT TISSUES AFTER TKA: THE MODIFIED TRACKING OF THE PT

After TKA implantation the tracking of the PT is greatly modified. This is true in case of oversized plateau in the AP dimension but also in apparently normosized implant (fig. 6). A normal tracking of the PT was observed only in specimens where the tibial component was significantly undersized on the lateral plateau.

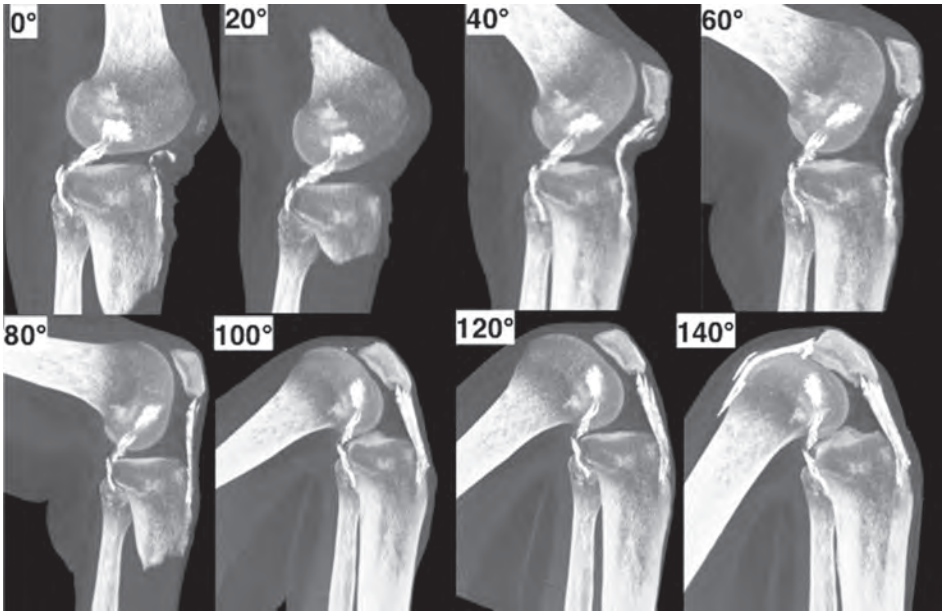

Fig. 5: These images are obtained from sagittal views of the normal knee during flexion, with thick slices visualizing the all PT (OsiriX software). The PT is white, due to the baryum injection.

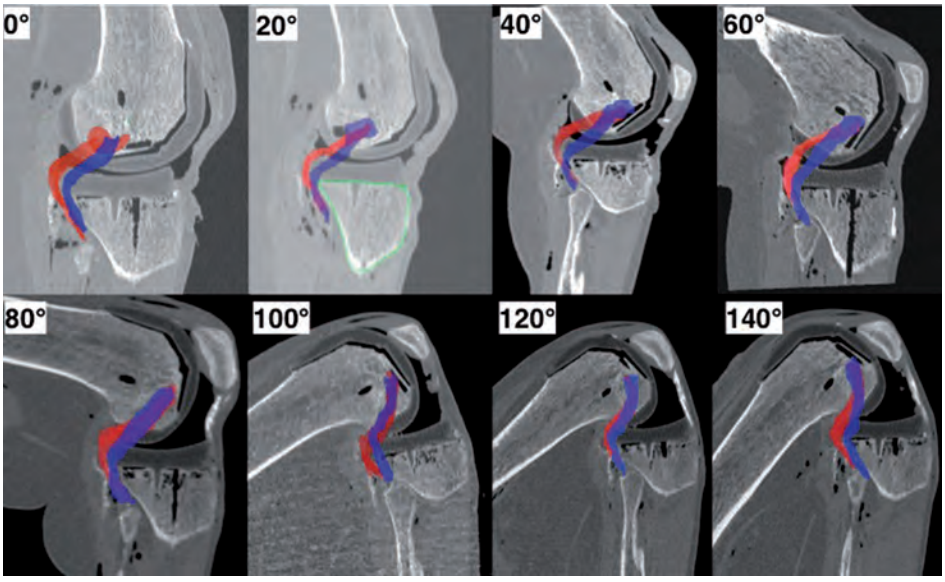

Fig. 6: On this specimen, an intentionally oversized TKA was implanted. The position of the PT before implantation (blue) and after implantation (red) are suprimposed. The tracking of the PT is obviously modified by the tibial plateau.

CONCLUSION

To our kowledge, this is the first investigation, which analyses the relationships between implants and soft tissues after TKAs'. This work demonstrates that the optimal sizing in TKA is very challenging due to the non-anatomic design of current implants. The main finding is that surgeons must analyse sizing in term of volume rather than in term of surface. In other words, most apparently "normosized" TKA, in term of surface coverage are in fact oversized in term of prosthetic volume. Therefore, with current implants we should aim at undersizing our implants, both in the mediolateral dimension (Femur & Tibia) and in the anteroposterior dimension (Tibia). Anteroposterior sizing of the femur is more complex because it may influence ligament balancing in flexion and at mid-flexion. At the anterior aspect of the femur (from overhang of the trochlea to anterior notching) malsizing can be a cause of anterior pain due to impingement with the Patellofemoral ligaments and with the anterior capsule. At the posterior aspect of the femur inadequate posterior condyle resection may compromises the results due to excessive ligament tension or laxity. Therefore, anteroposterior sizing at the femur is not purely dictated by anatomic considerations.

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THE REASONS FOR A CUSTOMIZED KNEE PROSTHESIS STEPPING OUTSIDE THE SQUARE

T. AIT SI SELMI, D. SHEPHERD, M.BONNIN

TOTAL KNEE REPLACEMENT – SUCCESS AND OUTCOMES

Total knee replacement (TKR) has become the standard treatment in severe degenerative joint disease of the knee [1], and the number of procedures is growing since its generalization in the late seventies [2].

Through constant advances in design and technology to improve results, TKR now has durable results, in terms of long-term fixation, wear and subsequent loosening. Reliability, as measured through survival rate with revision as the end point criteria for failure, is constantly improving [2].

But more recently, there is increasing emphasis on satisfaction and functional outcome as reported by validated outcome scores of the patient's perspective, irrespective of the mechanical success and the longevity of the prosthesis reported by joint registries and surgeons [3, 4].

This approach in assessment has led to more disappointing functional results if compared with traditional "objective" knee scores, 5 or with other arthroplasty techniques such as uni-compartmental knee replacement 6 and total hip replacement [7].

The main reasons for patient dissatisfaction are residual pain, (mainly anterior), instability or a limited range of motion, with inability to climb stairs or squat [8].

Outcomes can be affected by failure to technically achieve the surgical goal with surgeon volume being an important factor is success rate [9]. However outcomes of Total knee replacement are predominantly still unsatisfactory even in the best surgical hands, as the ultimate achievement of an appropriately aligned, balanced and naturally functioning knee is constrained by the limitations of current prosthetic design.

Improved preoperative planning and intra-operative navigation systems, and personalized cutting guides, have been developed as an attempt to improve the operator's reliability. But the benefit of assisted surgery remains unclear, with both level 1 evidence studies and systematic reviews reporting contrasting results on improvement of accurate alignment and actual improvement of functional outcomes [10-19].

THE 180° TRADITIONAL ALIGNMENT AND BALANCING

Historically the proposed aim for coronal alignment, as measured by the mechanical femorotibial angle (MFT angle), has been within ±3° of 0 degrees, and the longevity of TKR has been traditionally associated with neutral or slightly valgus coronal alignment [20-23]. Studies have demonstrated improved functional outcomes with coronal alignment within 3 degrees of neutral [24, 25]. Achieving a mechanical alignment of 0° in the coronal plane requires the placement of the femoral and tibial components perpendicular to the femoral and tibial mechanical axes respectively. In the case of the femur the mechanical and anatomical axes are not coincident and form the femoral mechanical anatomical (FMA) angle. As such a distal valgus cut is made with respect to the anatomical axis, which should be equal to the FMA angle. Generally during conventional TKA with standard instrumentation most surgeons use the same fixed distal valgus resection angle (4°-7°) for all their patients, although variable jigs are available.

This goal of alignment also has consequences on balancing flexion and extension gaps notably at the femoral end [26]. Balancing the knee can be performed by utilizing measured resection techniques and setting the posterior joint line perpendicular to the anteroposterior axis of the trochlear groove, parallel to the transepicondylar axis, externally rotated 3° with respect to the posterior condylar axis or parallel to the tibial resection in 90° of flexion with the use of gap-balancing technique aligned internal-external rotation of the femoral component.

With measured resection techniques there is a wide range of femoral rotation, instability and femoral condylar lift off during flexion to 90 degrees [27, 28]. Gap balancing produces more accurate gap symmetry and minimal instability but can raise the joint line [29], and is accurate for gap balancing at 0 and 90 degrees but not necessarily in mid flexion [30]. Patients who perceive these changes in stability, limb alignment, and joint level alignment may be dissatisfied. The more accurate gap symmetry of gap balancing does not produce better functional outcomes in cruciate retaining or posterior stabilized prostheses [29, 31].

Fundamentally the current knee prostheses are designed with the concept that the bone cuts and the ligaments are balanced in order to modify the knee so as to fit the prosthesis to the knee along these alignment principles of 0 degrees and working with a ‘square gap’.

Consequently, any intraoperative change in any one of factor of rotation, flexion, oversizing or balancing of components ultimately has consequences and compromises on the other parameters (fig. 1).

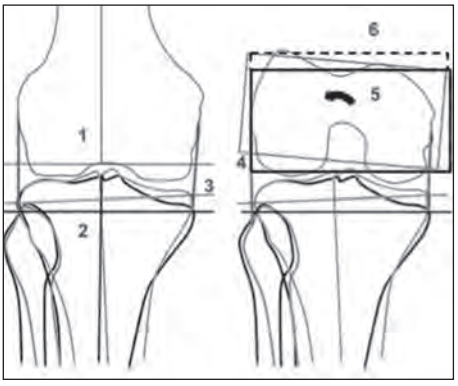

Fig. 1: Cascade of events resulting of traditional realignment in a typical varus knee. 1) The femoral perpendicular asymmetrical cut. 2) Tibial perpendicular asymmetrical cut. 3) MCL release to compensate extra-articular tibial deformity, thus changing the joint line level. 4) Grey rectangle underlying the posterior reference alignment, leaving an asymmetrical posterior gap. 5) Black rectangle showing external rotation where flexion gap balancing option is selected. 6) Broken line: increase of AP dimension as result of rotation with subsequent ML increase.

NATURAL ALIGNMENT AND BALANCING

The dogma of a target of an alignment of 180° crossing the prosthetic joint line perpendicularly

has been questioned as to whether it is essential to prevent failure [32], and it is not necessarily associated with better functional outcomes [33-36]. Some authors have promoted the restoration of a given degree of native deformity, especially when from femoral origin, along with the original joint line obliquity [37-42]. This concept may be reinforced by studies utilising CAS which have resulted in more accurate 'traditionally' aligned prostheses but without demonstrating superior functional outcomes [43, 44].

Moving closer to natural alignment may also be tolerated as improved prosthetic materials may tolerate variations in alignment in terms of wear rate [45].

The ideal rotational alignment is still the subject of controversy [46], and may be seen as a palliative attempt to offset an asymmetrical flexion gap and/or to make-up a poor patellar pace [47, 48].

THE RECENT ADVANCES IN PROSTHETIC DESIGN

Femoral Sizing and Shape

Independent from alignment factors affecting outcome, several publications have pointed out prosthetic design limitations regarding; sizing, AP/ML mismatch, and trochlear design [49]. AP sizing of the femur is dependent upon individual femoral anatomy and the degree of rotation and flexion of the femoral component chosen by the surgeon [50]. Selection of implant sizes between surgeons is variable depending on experience and philosophy [51], Overhang of the femoral component is highly prevalent, occurring frequently and with greater severity in women. Overhang also increases as larger femoral component sizes are used in both sexes. Femoral component overhang can double the risk of long term knee pain [52, 53] and lead to worse flexion and function [53]. Aside from overhang, the cut surface of the femur is often not covered adequately by the definitive prosthesis, leaving sharp edges on which the soft tissue envelope abuts (fig. 2 & 3). As a result, the most recently released prostheses are showing an increasing number of sizes across the range – extreme sizes being delivered on demand – with optional narrower femoral components and extended options to allow femoral and tibial dissociation (Table 1). However significant increases of shear strain occurs in the peripheral proximal regions of the tibia when loaded with a larger versus a smaller femoral component, indicating the importance of a correct sizing relationship [54].

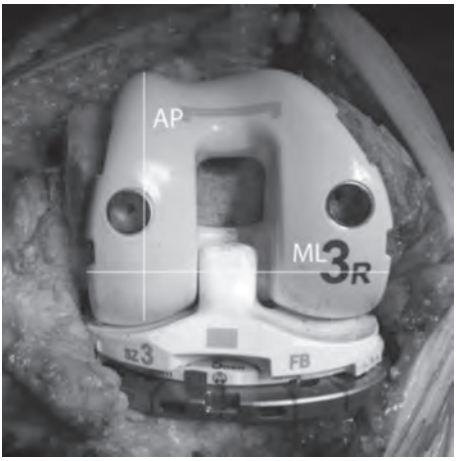

Fig. 2: Perfect AP/ML dimensioning in a female's right knee with a modern design implant.

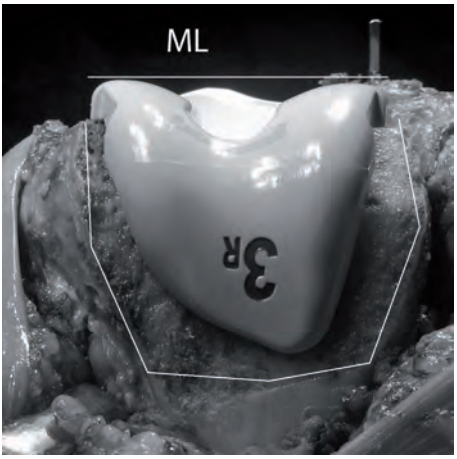

Fig. 3: Superior view of the same patient (figure 2) showing a lack of the trochlear coverage and subsequent sharp edges, despite perfect AP/ML dimensioning.

Table 1

	Femoral sizes options	Tibial Size Options	Max. Compatability Range between femur/tibia Size
Persona	12	9	6
Attune	10	10	4
Triathlon	8	8	Complete interchangeability
Journey	10	8	6
Genesis II	9	8	5
Vanguard	10	9	Complete interchangeability
Nexgen	11	10	5

Whilst attempting to adapt design to improve function, the large range of sizes and expanding ability for femoral – tibial size dissociation inherently illustrates the difficulty in matching a patient's specific anatomy and as such the potential risk in choosing the incorrect size for the femur and/or tibia of a given patient.

To further improve upon sizing issues, gender specific prosthetic sizes have been developed to counter the significant difference in distal femur proportions between men and women, as dimensions propagation of femoral components for TKA traditionally followed men's distal femoral anatomy dimensions. In addition, sizing of modern femoral components was traditionally based on an assumption that ML dimension increases proportionally to AP dimension [55]. Despite best attempts to modify shape and size the problem has not been completely addressed, and there is still a tendency for 'overhang' and 'underhang'. Analysis of six contemporary femoral components with multiple ML/AP shape offerings and an increased number sizes (Persona™, NexGen®, Sigma®, Genesis™ II, Triathlon®, Vanguard®) has demonstrated either persistent overhang or underhang characteristics of each prosthesis, despite some superiority of some prosthesis for greater cross ethnicity fit [56]. However these additional sizes for gender and enhanced ranges of size have previously not appeared to influence short-term outcomes [57].

Ongoing pain is also associated with soft-tissue impingement and may occur in up to 25%, of total knee arthroplasties. It is associated with a femoral component with a shallow trochlear groove or with a sharp transition to the intercondylar region of the implant, and poor patellofemoral tracking [58].

Tibial sizing and shape

Tibial sizing is an important issue as well. In any case, tibial tray or polyethylene liner overhang may lead to soft tissue impingement and subsequent pain (fig. 4). Asymmetrical

Fig. 4: TKR revision for medial pain. Intra-operative view of the polyethylene liner medial that is overhanging in a rotating platform knee in external rotation. The metal tray is well aligned with the bone cut.

tibial trays have also been emphasized, along with gentle 1mm liner thickness increment. The tibiofemoral joint is asymmetric in shape and dimension, and correct positioning of the tibial component must accommodate both optimal bone coverage and satisfactory patellofemoral tracking. As such a compromise must be found during the operation to meet these two requirements, as best bone coverage often internally rotates the tibial tray [59]. Asymmetrical trays reflect the tibial torsion more accurately, and may offer the best compromise for optimal bone coverage and patellofemoral tracking [58]. However symmetrical trays have also been reported to provide the best compromise for coverage and more kinematic rotation and tracking [60, 61].

Bony resection

Irrespective of individual patient's bone size and characteristics, bone resection requires a minimum bony cut that is not proportional to the patient's anatomy, in order to accommodate the prosthesis and bearing. This has greater consequence in smaller bones as the resection is at a level of poorer bone quality and in closer proximity to the level of the collateral ligaments.

On the femoral side a fixed resection level can encroach upon the collateral ligament insertions in small femurs, with the potential risk of prosthetic impingement upon the soft tissue envelope. On the tibial side a relatively large distal resection level results in a smaller component size for that knee, and overall a relatively posterior and peripheral displacement of the implant, and strain increases significantly in the proximal tibia during loading [62]. The deep MCL is a distinct medial stabilizer and plays an important role in rotational stability. With a standard 9-mm tibial resection up to 54% of the deep MCL insertion area may be resected, and it is resected in at least 1/3 of cases of conventional TKA. However it may have implications in future designs of both unicondylar and total knee arthroplasty [63].

Patello-femoral joint

Patello-femoral function and stair climbing has been shown to improve with more anatomic trochlea designs of the femoral component [64]. Trochlear designs have also been gradually modified to better accommodate the patellar articular facets, with broad extended asymmetrical trochlear grooves. The literature has conflicting evidence how effective this is in improving patella tracking [65, 66].

Patella resurfacing

Anterior knee pain remains a factor in patient dissatisfaction, and furthermore the role of patella resurfacing during primary total knee arthroplasty remains controversial. Whilst resurfacing may reduce actual revision rates [67]. The literature has shown no benefit from resurfacing of the patella in terms of outcomes [67, 68, 69]. This may be by differences in design between TKA brands. However a review of five popular primary knee designs demonstrated that patella resurfacing has no improvement in overall knee function or anterior knee-specific function irrespective of TKA brand or for cruciate retaining versus sacrificing designs [70].

Kinematics

Aside from sizing variations there are many variations available to try and improve the kinematics and function of the knee replacement by different means. Orthopaedic device companies have developed technical differences including; single radius of curvature femoral components, graduated radius of curvature components, medial pivot designs, third condyle and high flexion femoral component designs to attempt to achieve kinematics matching the native knee. Third condyle designs have demonstrated similar anteroposterior and medial-lateral ligamentous stability compared to the native knee [71]. There is some evidence single radius designs

improve functional outcomes [72], however literature does not support any superiority of high flexion devices [73, 74].

The bearing platform itself has variations of posterior stabilized, cruciate retaining, rotating platforms and deep dished platforms to try and enhance kinematics such as deep flexion and maintain flexion stability. There is controversy over whether any are more superior. There appears to be no difference between fixed or rotating platforms [75], and they fail to achieve the anteroposterior stability of the native knee, furthermore some designs have failed to prevent paradoxical rollback/tibial external rotation. Cruciate retaining designs theoretically may improve function by maintaining proprioception [76], whereas posterior stabilized designs have evolved to enhance flexion. Whilst posterior stabilized knees may provide deeper flexion [77], the evidence in the literature shows that there is no difference in outcomes functionally between the two groups [77, 78, 79].

Overall, despite best attempts to improve the performance of knee arthoplasty, these modifications to existing implant design and rationale have not necessarily improved outcomes in active patients [80]. All in all, the trend that we all see is clearly an attempt to attain a prosthetic design that can better match the native knee, and current 'off the shelf' designs still utilize the model whereby the knee is made to fit the prosthesis, rather than the prosthesis fitting the knee, such that intraoperative modifications of one parameter will have consequences on another.

The question then remains, why are we not attempting to leapfrog these steps to a customized prosthesis?

THE CONCEPT OF CUSTOMIZED KNEE ARTHROPLASTY

The general idea of customization is to prevent the need for compromises that the surgeon is forced to make during standard TKR insertion and to minimize the accumulation of approximations from preoperative planning to final implant insertion. Customization is an appealing option but 3 principle questions arise: **1-**, What type of deformity can be addressed or what (native) residual alignment is acceptable? **2-** What parts of a TKR may benefit from customization? **3-** How to execute it at an industrial level?

Reaching the native alignment

The amount of acceptable native alignment (incorrectly termed "deformity") is somewhat difficult to determine, but as mentioned previously, 3 to 5 degrees of residual alignment may be acceptable, as recommended in unicondylar knee arthroplasty. This amount of angulation is acceptable provided that the ligaments (including the cruciates) are intact, and probably in patients under a maximum weight or BMI. These criteria would make the customized knee ideal for patients where both cruciates are intact. But in TKR the stabilization mechanism can be used to compensate for the absence of one or two cruciates, and thus customization can presumably be extended to more patients. On the other hand, fixed deformities, major ligament instability, or severe extra-articular deformities should be contraindications.

The native alignment does not cover the limb alignment alone but includes the joint line obliquity. In a customized knee concept this native angulation can be respected. This has consequences on ligament balancing, making it simpler because it does not create a flexion-extension miss-match from a femoral origin. Keeping the native joint obliquity results in restoring – or approaching – the individual medial-lateral femoral contours. In principle, in keeping the native knee contour there should be no further need for ligament release or it should be limited to address limited contractures (fig. 5). Such a design, while reducing the flexion extension imbalance may provide a smoother stability across the range of motion, thus reducing the mid flexion instability. Along

with better stability, keeping the ligament insertion intact and getting closer to the natural tension may reduce a significant source of potential residual pain.

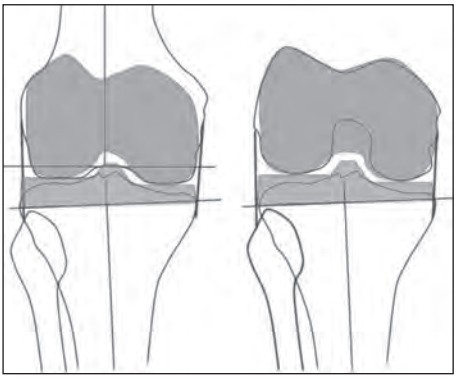

Fig. 5: Aspect of customized knee prosthesis with a residual 3° of native deformity and oblique joint line restitution through asymmetrical femoral and tibial design.

WHAT TO CUSTOMIZE?

Bone coverage

Aside from the customization of the femoral condyle contour to restore the biomechanics, the restoration of bony coverage is aimed to maintain the natural smooth transitions at the new articular surface – bone interface, including the bone cuts created to accommodate the prosthetic box. The miss-match resulting from the cuts and the implant generates either overhang of the implant in some areas or exposed sharp bony cuts in other places. These miss-matches are responsible for soft tissue impingement or overstuffing and may generate stiffness, irritation, or pain and discomfort that affect the clinical result. At the trochlea area the miss match is often large, due to proximal propagation of the cut, and the possible rotation or flexion of the cutting guide. Customization of the femoral contour, along with bony coverage, eliminates the AP/ML dissociation issue and many sources of impingement. The femoral box can also be designed in a more proportional and bone sparing way, especially in smaller sizes, where the miss match is increased when using a fixed, standard amount of resection.

On the tibial side, the accurate coverage of the bone surface not only protects against possible ligament impingement but also enhances implant fixation. The amount of resection, slope and the frontal obliquity of the cut do affect this surface, making the planning essential to approximate the ideal contour.

Kinematics

The kinematics of the knee is essentially guided by the articular surface contours but orchestrated by the ligaments. In the normal knee the femoro-tibial junction is subtly composed of cartilage and menisci that creates a complex and harmonious transfer across the range of motion. But in knee prostheses, the current necessity to use a stiff material that has a wear rate, namely polyethylene, prevents exact restoration of the native surface contour, whether it is standard or customized, even in presence of both cruciate ligaments. Thus one of the main design challenges in customized implants is to match the prosthetic femoral anatomical contour to the polyethylene in a form that can be reproducible and compatible with material resistance. In other words, there is still a need to maintain a given degree of conformity and to use a mechanism (such as a cam, post, third condyle, etc.) to provide a sufficient degree of congruency. It is possible to achieve this challenge through an algorithm that will match a particular type of stabilization mechanism with a given medial/lateral femoral contour from a number of knee sub-groups, based on a family of similar anatomical features. Thus the kinematics cannot be totally customized, but adopted and adapted, from a proven reliable solution.

Apart from femoro-tibial kinematics, patella tracking is probably the most important area which offers a large amount of room for improvement. The reproduction of the native patellar-trochlear anatomy is undoutably one of the more promising areas of progress. In a

custom implant the trochlear design and positioning is not compromised as in conventional techniques, by the variation of the femoral component positioning guided by flexion/extension gap balancing. The patellar resurfacing debate remains open, but more natural tracking should allow sparing of the native patellar surface more frequently.

Fixation

A strong and harmonious fixation is usually achieved in most of the patients with modern designs. The fixation may nevertheless be challenged in some situations. Typically in overweight females with small joints the fixation interface is reduced and fixation can be compromised. This can also occur when a residual deformity is present, especially a varus deformity. The use or addition of longer stems or fins is required in these situations. But the reduced surface resulting from the cut, or the lack of metaphyseal volume, or the presence of a narrow diaphysis can make the insertion of these extensions challenging. The shaft alignment may also be challenging since it is not always centered on the cut due to the local anatomy or in relation to the obliquity of the cut in both frontal and sagittal planes. In customized knees this can be anticipated, and the additional fixation extensions or devices, can be aligned and proportioned accordingly. The use of more proportional implant thickness allows the reduction of the bone resection in smaller patients, thus offering a wider and stronger bony site, typically on the tibial side. The femoral and inter-condylar boxes can also be reduced in order to maximize bone sparing whilst providing better fixation.

HOW TO DO IT?

Technique

The last but not least surgical challenge is the insertion of the implant. In customized implants there is no role for traditional instrumentations or intra-operative on the spot decision-making. The whole procedure and specific adjustments must have been anticipated during the planning and the implant design phase that will generate the patient specific cutting guides. The actual alignment and the various contributions to the deformity, including wear, ligament imbalance and native deformity must be determined as accurately as possible. From this analysis, the reducibility of the deformity must be calculated as accurately as possible to approximate the final limb alignment. So far there is no absolute way to predetermine the final alignment, this is why there should be some degree of patient selection and some room for intra-operative adjustments. The reducibility of the preoperative alignment can be estimated on stress x-rays and the overall analysis of the deformity based on a 3D model extracted from a CT-scan. Because the femoral implant is the key element in determining the future kinematics of the joint, its position cannot be adjusted much during the surgery, whereas on the tibial side it is easier to perform fine-tune by adjusting the cut in depth and direction. This option must be implemented in both the tibial design and the instrumentation (fig. 6).

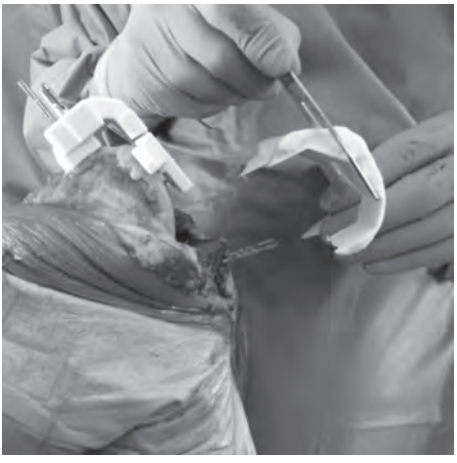

Fig. 6: Accuracy of a personalized femoral cutting guide along with the bony model that allows a final matching check before realizing the bone resection.

Manufacturing process

In order to confirm the feasibility of such a project, we performed a limited series of 12 customized patient specific postero-stabilized total knees with a fixed bearing, after appropriate patient consent. Out of this preliminary experience we were able to demonstrate that the cutting guides were accurate and that the prostheses could accurately match the native knee. We do believe that building a customized implant is achievable (fig. 7, 8).

The real challenge is then to demonstrate a clinical relevance and durable advantage of this option in every surgeon's hands compared to the modern range of implants. So far none of the current attempts have yet produced consistent published results.

Generalizing the process is another challenge. The implant design process requires several steps that cannot all be automated so far, including; clearance of osteophytes, estimation of cartilage wear, establishing suited kinematics, positioning of the posterior stabilization cam and alignment of the segments, etc. An individual surgeon cannot be asked to give his contribution for every single case plan. As such there is a need for detailed algorithm based upon large patient anatomic bases crossed with the design features.

Whether the image generation is CT based or MRI based is still a subject of debate. Also, collecting data with reliable imaging and transferring them in a safe way is another vast investment. Finally the manufacturing process is an additional new challenge: one cast for one patient is not currently a sustainable solution. Selecting the ideal and affordable manufacturing process along with subsequent specification requirements and legal compliance issues is not an insignificant hurdle.

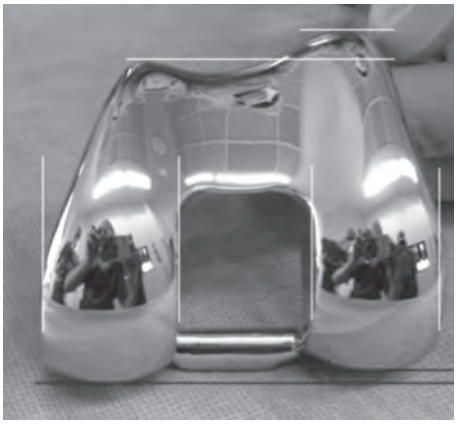

Fig. 7: Customized femoral implant. The distal and posterior contours are symmetrical and in line with the tibial tray, but the condyles are not identical and replicate the native sagittal condylar contours and respective sizes.

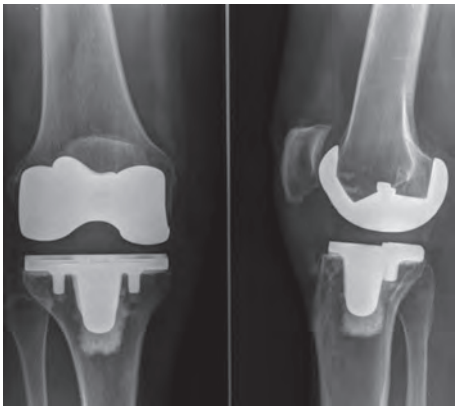

Fig. 8: One year postoperative radiograph of a right customized TKR in an young and active female patient.

CONCLUSION

Custom made implants offer a chance to significantly improve both the life of the patient and the job of the surgeon. This fascinating adventure is a rather complex challenge. Ultimately, mailed delivery of a personalized implant, along with its specific disposable instrumentation in a single box will be a major improvement for the manufacturer, the surgical institutions and the payers. The question remains: is the initial investment worth the potential benefit? It is likely that successful surgical pioneers would agree!

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CUSTOM ANATOMIC CR TKR

W. FITZ

POTENTIAL SHORTCOMINGS OF OFF-THE-SHELF TKA

Patient dissatisfaction following off-the-shelf TKA is up to 20%. It is unclear what variables are relevant to improve results of TKR. Potential factors are:

- Implant overhang [1]
- Malrotation of femoral and tibial components [2, 3, 4]
- Unreliable surgical anatomic landmarks
- Joint line is not restored
- Asymmetric distal condylar geometry is replaced with a symmetric condylar design
- Distal condylar valgus is not restored given the high variability [5] (fig. 1)
- Proximal tibial condylar anatomy is not restored [5] (fig. 2).

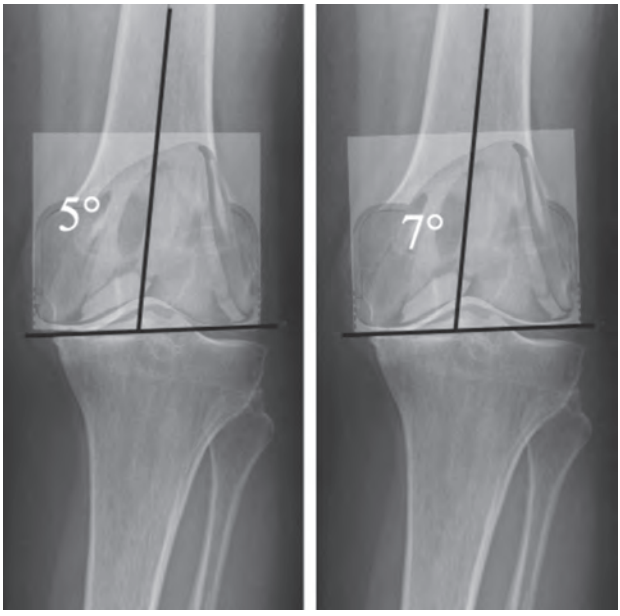

Fig. 1: The distal femoral condyle has a larger range of varus or valgus than just 5 or 7 degrees. Comparing osteoarthritic (n=80) with non-osteoarthritic patients (n=356) the mean 5.4°, ± 3.3 (6° varus to 11° valgus) and 5.2 °, ± 3.0 (3° varus to 13° valgus) in the control group 14.

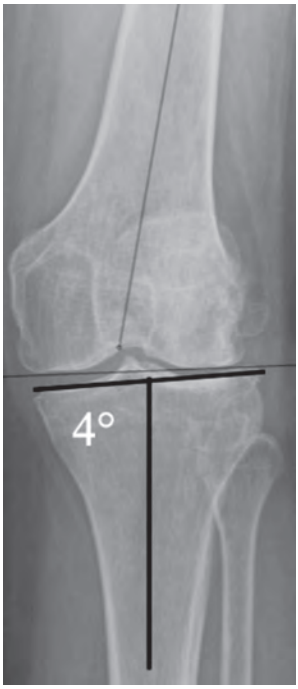

Fig. 2: The proximal tibial condyle has a large range of varus or valgus. Comparing osteoarthritic (n=80) with non-osteoarthritic patients (n=356) the mean was 1.1° varus ± 1.2° (6° varus to 3° valgus) in the osteoarthritic group and 0.8° varus ± 1° (4° varus to 4° valgus) in the control group 14.

New surgical techniques try to approximate the restoration of the femoral and tibial anatomy called "shape matching" [6, 7] which challenges principals of TKR such as tibial components is in too much varus. "Shape matching" does not improve knee kinematics [8].

Current surgical techniques do not restore the posterior medial condyle. With more femoral external rotation the amount of resected posterior medial condyle exceeds implant thickness (fig. 3). Moving the pivot point to the surface of the posterior medial condyle and resecting the implant thickness off the posterior medial condyle would restore the medial condyle and decrease the looser lateral flexion gap (fig. 3).

Matching the proximal tibial varus and valgus angle using a symmetric tibial implant results in substantial numbers of tibial components placed in more than 3 degrees of varus [7].

CUSTOM TKA ADDRESS SHORTCOMINGS OF OFF-THE-SHELF IMPLANTS

Custom implants address high variability and range of different AP and ML dimensions.

Asymmetric anatomic condylar geometries restore the distal femoral condylar anatomy.

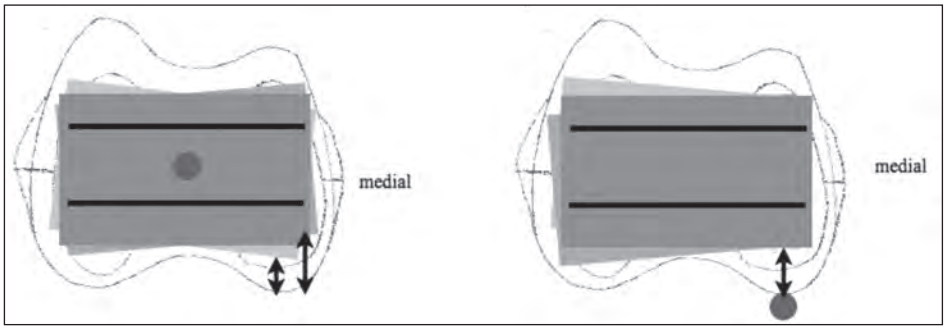

Fig. 3: The pivot point for femoral rotation is in the center of the distal femur and external rotation of the femoral component results in increased bone resection of the medial condyle and less of the lateral posterior condyle not matching the implant thickness. Moving the pivot point to the posterior surface and resecting the implant thickness off the posterior medial condyle would restore the medial condyle and decrease the looser lateral flexion gap.

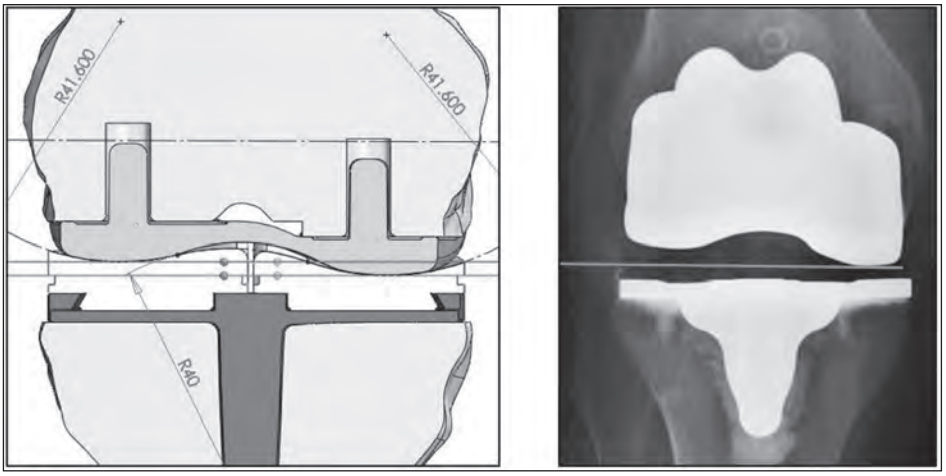

Fig. 4 a and b: In custom TKR the distal femoral condylar geometry is restored and based on a perpendicular cut of the tibia the space on the lateral side is filled with polyethylene to restore overall alignment.

Variable thick medial and lateral inserts allow a 90 degree cut perpendicular to the tibial mechanical axis, but restore proximal tibial anatomy.

Restauration of the distal femoral condylar anatomy and proximal tibial joint line restore and correct the limb malalignment (fig. 4).

Rotation of the femoral component is based on the restoration of medial and lateral J-curves. The rotation of the tibial component is designed using the Cobb's method [4] but slight undersizing allows correction of rotation if necessary following either the position of the tibial tray during range of motion or orienting the component toward the tibial tubercle as recommended by Lawrie *et al.* [9].

Early clinical results report less blood loss, bone preservation.

Early cadaveric kinematics studies confirm the hypothesis that restoration of the distal femur and proximal tibia resemble more closely normal knee knee kinematics compared to off-the-shelf implants comparing knee kinematics before and after surgery [10].

Early clinical results are encouraging and report less bone resection, less ligament releases and good mechanical alignment [11-13].

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BICRUCIATE-RETAINING TKA: A CONCEPT WORTH EXPLORING

F. LAVOIE, K. IGUER, F. AL-SHAKFA

Doctor Jean-Marie Cloutier is a pioneer of knee arthroplasty. In the late seventies, the inventive surgeon imagined a way to replace worn articular surfaces of the knee while preserving its native ligaments [1]. The concept he proposed was to minimize prosthetic constraints and let knee motion and stability be dictated by the soft tissues. Through commercial partnerships, he developed an implant that turned out to be one of the very few to remain in use for decades without significant design modifications. Currently it is implanted by only a handful of surgeons worldwide: why is that so?

BETTER KNEE KINEMATICS…

The most logical way to restore or preserve normal function is to replicate or preserve normal anatomy. The field of orthopedic surgery is filled with demonstrations of this principle for every part of the human body. Cloutier understood that: in addition to preserving all the knee ligaments, he designed the prosthetic femoral component to replicate the shape of the human femur, including an asymmetrical trochlear groove, a first at the time. Therefore, it is perhaps not surprising that his bicruciate-retaining knee prosthesis outperformed various posterior-stabilized (PS) and posterior-cruciate-retaining (CR) designs in their ability to restore normal knee kinematics [2-3]. Other studies also showed that patients implanted with different arthroplasty designs in their left and right knees preferred the bicruciate-retaining design over PS and CR implants [4-5]. Knowing that, shouldn't this technique be widespread?

…BUT STIFFER KNEES?

Obviously, better knee kinematics in a gait lab and patient preference don't tell the whole story. Many surgeons stopped performing bicruciate-retaining arthroplasty as they felt it resulted in stiff knees more often than with CR or PS arthroplasty. This perception was reinforced in the orthopedic community by Goutallier *et al.* who reported that knees with a bicruciate-retaining implant were in average stiffer and more painful than with a PS implant [6]. These conclusions should however be regarded with caution as they were drawn from a non-randomized retrospective study with significant differences between the groups for pre-operative weight, height, frontal alignment, and AP laxity; pre-operative flexion also differed between groups but did not reach clinical significance; most importantly, the surgical technique was not the same for the two groups. Indeed, the extra-articular tensioning device developed by Cloutier was only used for

the bicruciate-retaining implants and, as acknowledged by the authors, in an inappropriate fashion, probably resulting in insufficient tibial resections and femoro-tibial overstuffing. Considering this and the fact that other series didn't suggest decreased flexion with bicruciate-retaining implants [4, 7-9], it is reasonable to think that knee stiffness after a bicruciate-retaining knee replacement may result more from technical errors than from an intrinsic design flaw.

ACL DEGENERATION AND LONG-TERM SURVIVAL

Based on histological studies suggesting that the ACL is often degraded in osteoarthritic knees [10-12], concerns have been expressed about the risk of preserving it during arthroplasty as it may eventually rupture and lead to knee instability and failure of the implant. Reported survival rates for the bicruciate-retaining variant of the LCS system *(DePuy Orthopedics, Warsaw, Indiana, USA)*, however, do not substantiate such a fear: 90.9% survival at twelve years for Buechel and Pappas [7] and 79% survival at fourteen years for Hamelynck *et al.* [13]; none of these two studies mentions ACL rupture or knee instability as a cause of failure. A series of 163 bicruciate-retaining knee replacements *(Hermes 2C, Ceraver Osteal, Roissy, France)* in 130 patients had a 95% survival rate at ten years [8] and 82% at 22.4 years [14], also not providing evidence that a degenerated ACL may threaten the survivorship of the knee implant. On the contrary, the latter study didn't show any difference in survival, Knee Society scores, and polyethylene wear between the knees in which the ACL was visually deteriorated but functional (41%) and the knees in which it was visually intact (59%). In the same study, symptomatic knee instability was noted in eight knees (4.9% of the initial cohort, 27.6% of revised knees) after a mean follow-up of 15.5 years (11.7 to 22.3) and was always associated with severe wear of the tibial polyethylene inserts, suggesting polyethylene wear to be the primary cause of instability rather than ligament rupture. Our hypothesis is that scarring occurs in the intercondylar notch after bicruciate-retaining TKA; the properties of this scar tissue have not yet been studied but may be involved in ACL protection and may be correlated to post-operative range of motion. Regardless of the mechanism, current evidence shows that bicruciate-retaining knee arthroplasty is a viable option in terms of survival, even when the ACL is visually deteriorated.

A BONE-PRESERVING SURGERY

Retention of the anterior cruciate ligament during total knee arthroplasty involves preserving the intercondylar eminence of the tibia and requires no bone resection in the intercondylar notch of the femur, making bicruciate-retaining TKA a bone-preserving procedure and, logically, making revision surgery easier if it becomes indicated. This theoretical advantage was confirmed by Sabouret *et al.* who reported that no intramedullary stems or metal augments were necessary for 26 of the 29 bicruciate-retaining TKAs (90%) that required revision in their series [14]. Osteolysis was not a significant problem in their series as it was noted in seven revised knees but required stemmed components in only one case. The bone-preserving nature of bicruciate-retaining arthroplasty could make this design a better option than PS and CR TKA for younger and more active patients requiring a knee replacement as multiple revision surgeries can be expected for such patients. This hypothesis remains to be verified, however.

SURGICAL TECHNIQUE EVOLUTION

In a bicruciate-retaining arthroplasty, stability and motion rely completely on the ligaments and capsule of the knee, consistent with the principle of minimal prosthetic constraint articulated by Cloutier. Consequently, ligament balancing is a critical aspect of this surgery. Cloutier tackled this challenge by devising an instrumentation that featured extra-articular

alignment rods, coupled cutting blocks and, importantly, an extra-articular tensioning device [1]. His technique proved to be efficient in obtaining identical rectangular extension and flexion gaps. Also, as the AP femoral cuts were made perpendicular to the mechanical axis of the tibia, the femoral component was serendipitously positioned in slight external rotation, a concept that was not yet described [15]. However, adopters of this technique found it cumbersome and overly complex, especially the extra-articular tensioning device. This, combined with the increasing popularity of simpler techniques involving cruciate ligaments resection and independent cuts, contributed greatly to the limited spread of the concepts put forth by Cloutier among the orthopedic community.

The technique of bicruciate-retaining knee arthroplasty was recently revisited to make it simpler while adhering to the same surgical philosophy. In this new surgical method, the extra-articular tensioning device is replaced by a system of spacer blocks (fig. 1). The surgical sequence was modified and is detailed in Figure 2. This technique consistently results in

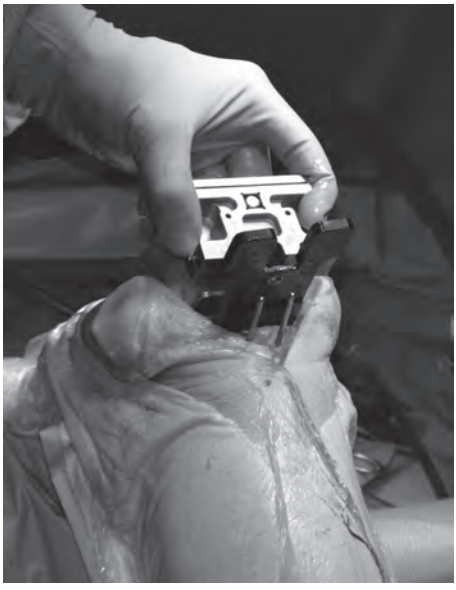

Fig. 1: Revisited surgical technique : Cloutier's extra-articular tensioner was replaced by a system of spacer blocks ans shims.

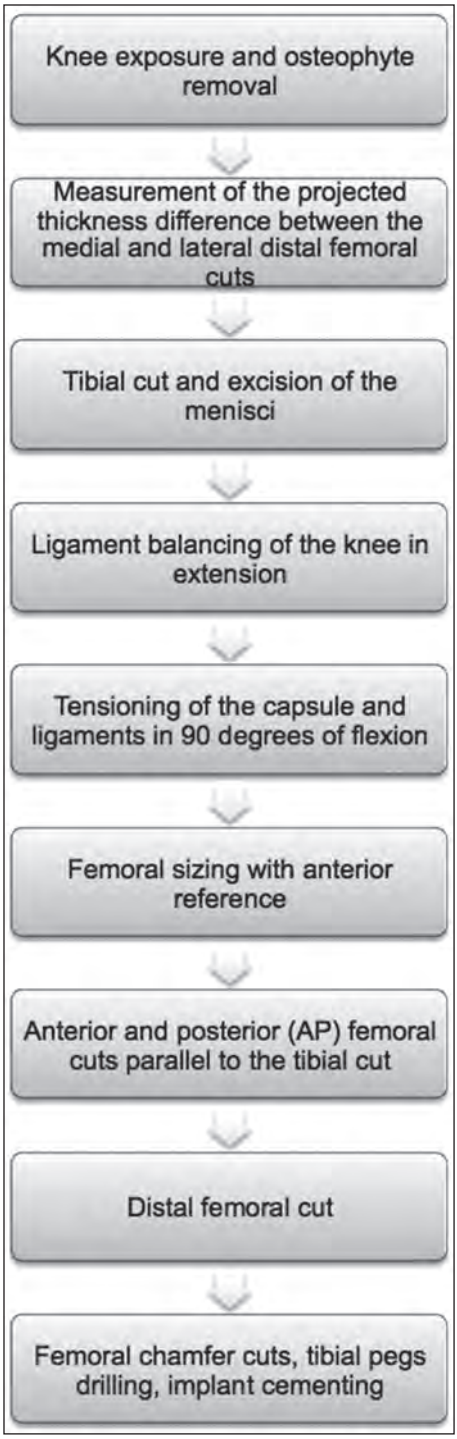

Fig. 2: Revisited bicruciate-retaining TKA surgical sequence.

identical rectangular extension and flexion gaps, similar to the original technique of Cloutier, however the surgical flow is smoother and operative times are comparable to other knee arthroplasty techniques.

CLINICAL RESULTS

The first 100 bicruciate-retaining TKAs performed with this implant and the revisited technique *(Hermes 2C, Ceraver Osteal, Roissy, France)* by the first author were reviewed. A cohort of 100 posterior-stabilized TKA *(Hermes PS, Ceraver Osteal, Roissy, France)* matched for sex and height with the bicruciate-retaining arthroplasty cohort also performed by the first author was also reviewed as well (Table 1). The shape of the femoral component of the two implants is essentially identical, other than the intercondylar portion; both implants offer essentially no rotational constraint in the transverse plane; finally the surgical technique for the two cohorts is the same, other than the preservation of the cruciate ligaments: it is therefore reasonable to think that this comparative study, although far from perfect, can provide some insight on the impact of preserving both cruciate ligaments during TKA.

Our results confirm that bicruciate-retaining TKA results in good clinical outcomes with significant improvement of the two components of the Knee Society (KS) score and of all five components of the KOOS (Table 2). Knee instability was not an issue for the two cohorts, most probably because of the surgical technique that was used. However, like Goutallier *et al.* [6], we observed a decrease in maximal knee flexion at the last follow-up. In our series, the 2C knees lost an average of 8 degrees of flexion compared to the pre-operative value, while the PS knees gained an average of 5 degrees of flexion. Also, five patients with a bicruciate-retaining prosthesis had a mobilization of their knee under general anesthesia compared to none in the posterior-stabilized cohort.

Table 1: Pre-operative data for Bicruciate-retaining (2C) and Posterior-stabilized (PS) TKA cohorts.

	2C	PS	p value
Number of knees	100	100	
Number of patients	90	88	
Male/Female	37/63	34/66	0,658
Age (range)	63 (45-83)	67 (43-85)	0,002
Weight (kg)	89,5	81,3	0,003
Height (m)	1,65	1,65	0,687
Medial HKA angle (range)	174,5 (163-191)	174,3 (153-194)	0,807
Knee flexion contracture (range)	1,3 (0-15)	2,4 (0-20)	0,051
Knee flexion (range)	127,2 (100-160)	119,8 (40-160)	0,030
KS Knee Score	48,7	44,1	0,089
KS Function Score	56,6	53,5	0,262
KOOS - Pain	33,4	35,3	0,500
KOOS - Symptom	39,1	40,6	0,613
KOOS - Activities of daily life	38,0	37,6	0,875
KOOS - Sporting activities	12,0	11,9	0,972
KOOS - Quality of life	20,6	22,3	0,560

Table 2: Post-operative data for Bicruciate-retaining (2C) and Posterior-stabilized (PS) TKA cohorts.

	2C	PS	p value
Follow-up length (months; range)	18 (5-50)	38 (13-71)	<0,001
Tourniquet time (minutes; range)	53 (32-112)	58 (36-113)	0,003
Patellar resurfacing (%)	18	85	<0,001
Medial HKA angle (range)	179,3 (171,8-185,8)	179,1 (171,9-187,5)	0,725
Knee flexion contracture (range)	1,5 (0-15)	0,7 (0-15)	0,034
Flexion at end of surgery (range)	132 (110-140)	127 (80-140)	<0,001
Flexion at last follow-up (range)	118 (80-150)	124 (60-150)	0,006
KS Knee Score	83,9	89,2	0,026
KS Function Score	75,1	75,6	0,874
KOOS - Pain	72,9	75,9	0,413
KOOS - Symptom	68,8	75,3	0,400
KOOS - Activities of daily life	74,9	75,4	0,894
KOOS - Sporting activities	39,2	42,1	0,564
KOOS - Quality of life	61,1	69,0	0,075

We investigated stiffness by splitting each cohort in two groups, stiff knees and flexible knees. A knee was considered stiff if it lost 10 degrees of flexion or more at the last follow-up compared to pre-operative flexion; knees with a flexion contracture of 5 degrees or more at the last follow-up were also labelled as stiff, no matter if a flexion contracture was noted before surgery (Table 3). Using these criteria, 61% of the bicruciate-retaining TKA were stiff (three because of a knee flexion contracture, 44 because of decreased flexion, and 14 because of both); 35% of the posterior-stabilized knees were stiff (seven because of a knee flexion contracture, 27 because of decreased flexion, and one because of both). An interesting finding is that, in the two cohorts, stiff knees had significantly more flexion before surgery than flexible knees, but gained less flexion during surgery, and lost more flexion during the post-operative period.

So far we failed to explain why some knees stiffened and others didn't, although we analyzed numerous factors including the thickness and the alignment of bone cuts, implant size, and ligament releases. However, we noted that bicruciate-retained knees, either stiff or flexible, lost more flexion than the posterior-stabilized knees during the post-operative period. Considering this, plus the fact that knee stiffening was almost twice as likely to occur with bicruciate-retaining TKA as with posterior-stabilized TKA, it seems obvious that the cruciate ligaments play a role. Plausible mechanisms include technical errors, intercondylar fibrosis, and/or nociceptive feedback from the cruciate ligaments. Patient factors are also probably involved: indeed, most patients of the reported cohorts that had a TKA performed in both of their knees had a symmetrical outcome regarding knee stiffness (80% of 2C knees and 83% of PS knees). Our current hypothesis is that minor technical errors are common during performance of any type of TKA, but that the knee is less forgiving for them when the cruciate ligaments are retained. The reasons for this still need to be clarified.

Table 3: Stiff knees vs Flexible knees.

		Bicruciate-retaining			Posterior Stabilized		
		Stiff	**Flexible**	**p value**	**Stiff**	**Flexible**	**p value**
Pre-operative	Male/Female	24/35	13/24	0,59	10/25	24/41	0,400
	Age	62,6	63,4	0,64	68,8	66,6	0,29
	Weight (kg)	91,4	85,4	0,16	76,2	84,0	0,04
	Height (m)	1,66	1,65	0,71	1,63	1,67	0,21
	Medial HKA angle	174,3	175,2	0,46	174,7	174,0	0,69
	Knee flexion	130,9	121,4	0	130,6	114,0	<0,001
	KS Knee Score	50,9	44,9	0,09	44,8	43,8	0,78
	KS Function Score	58,1	54,1	0,33	53,1	53,7	0,89
	KOOS - Pain	35,4	30,2	0,27	33,7	36,3	0,46
	KOOS - Symptom	40,8	36,3	0,36	38,9	41,5	0,51
	KOOS - ADL	41,7	32,1	0,07	36,7	38,1	0,7
	KOOS - Sport	14,6	7,7	0,09	11,3	12,3	0,77
	KOOS - QoL	23,4	16,0	0,15	18,3	24,6	0,100
Surgery	Tourniquet (mins)	51,4	53,8	0,36	56,9	58,4	0,63
	Patellar resurfacing (%)	18	18	0,97	77	89	0,11
	Flexion at end of surg.	132,8	130,0	0,01	131,0	124,8	0,01
Last follow-up	Follow-up (months)	18 (6-47)	19 (5-50)	0,62	40 (13-71)	38 (14-65)	0,62
	Medial HKA angle	179,3	179,6	0,55	179,8	178,8	0,17
	Knee flexion	115,1	125,4	<0,001	119,4	126,8	0,03
	KS Knee Score	81,7	87,7	0,15	86,4	90,7	0,09
	KS Function Score	73,3	77,9	0,37	73,7	76,6	0,47
	KOOS - Pain	69,9	77,7	0,18	71,4	78,4	0,13
	KOOS - Symptom	63,5	77,6	0,01	70,4	78,0	0,07
	KOOS - ADL	72,1	79,6	0,21	73,1	76,7	0,45
	KOOS - Sport	36,9	43,1	0,42	35,5	45,9	0,12
	KOOS - QoL	58,4	65,6	0,35	64,8	71,3	0,23

INDICATIONS

It was already shown that bicruciate-retaining TKA can be safely performed in patients with osteoarthritis or rheumatoid arthritis as long as the native ACL is continuous and functional, even if the ligament is visually deteriorated [14]. Other than that, the evidence on the indications and contra-indications for this technique is limited. Bearing in mind that the two cohorts reported in this paper are dissimilar in various aspects, their analysis nonetheless provides some hints on when bicruciate-retaining TKA should be performed or avoided.

Intuitively, one may think that knees with a larger pre-operative coronal misalignment are more difficult to balance during surgery and are less likely to have a good outcome after bicruciate-retaining TKA. In our series, however, severe pre-operative coronal misalignment, defined as more than ten degrees of varus or valgus, did not appear to negatively affect the results of bicruciate-retaining arthroplasty; on the contrary, knees with a severe misalignment seemed to benefit more from their surgery than those with a lesser misalignment with regard to the Knee Society and KOOS scores. Tourniquet times were five minutes longer with severely misaligned knees, either varus or valgus, reflecting the time necessary to perform ligament releases, but otherwise no difference was found between more severe and lesser misalignments. These groups may eventually prove to have different knee kinematics and/or a different long-term outcome but this remains to be seen. As of now there is no evidence that pre-operative coronal alignment of the knee has an influence on the outcome of bicruciate-retaining TKA.

Knees with a pre-operative flexion of 130 degrees or more lost in average 12 degrees of flexion after a bicruciate-retaining TKA and 8 degrees after a posterior-stabilized TKA, while knees with less than 130 degrees of flexion before surgery lost an average of 4 degrees after a bicruciate-retaining TKA but gained an average of 13 degrees after a posterior-stabilized TKA. This is significant, as this may lead to more patients not able to flex their operated knee to 110 degrees, the commonly cited flexion angle required to climb down stairs fluently. Indeed, knees with decreased pre-operative flexion were more likely to have less than 110 degrees of flexion after surgery if a bicruciate-retaining TKA was performed (21 out of 46, or 46%) compared to a posterior-stabilized TKA (14 out of 63, or 22%). Flexion of less than 110 degrees was a rare occurrence after both types of TKA when pre-operative flexion was 130 degrees or more: 2 out of 54 cases for bicruciate-retaining TKA (4%) and one out of 37 cases for posterior-stabilized TKA (3%).

When a knee flexion contracture was noted pre-operatively, it was more likely to recur after surgery if a bicruciate-retaining arthroplasty was performed instead of a posterior-stabilized prosthesis. More specifically, 50% of knees with a pre-operative flexion contracture of 5 degrees or more (8 out of 16) had a post-operative flexion contracture of 5 degrees or more if a bicruciate-retaining TKA was performed, compared to 18% (5 out of 28) if a posterior-stabilized TKA was done. When considering a pre-operative knee flexion contracture of 10 degrees or more, the rate of persistent post-operative flexion contracture climbed to 71% if a bicruciate-retaining TKA was performed (5 out of 7), but was essentially the same if a posterior-stabilized TKA was done (20%, 3 out of 15). When no pre-operative flexion contracture was present, it was nonetheless found in 11% of bicruciate-retaining knees (9 out of 84) and in 4% of posterior-stabilized knees (3 out of 72).

Based on the presented results, and until we understand better what causes some knees to lose flexion after bicruciate-retaining TKA, we think that this procedure should probably be avoided if, before surgery, maximal knee flexion is less than 130 degrees and a flexion contracture of 5 degrees or more is present. Otherwise, as long as the ACL is functional and that the bone stock is not compromised, bicruciate-retaining TKA can be safely performed.

CONCLUSION

Bicruciate-retaining total knee arthroplasty is a bone-preserving surgery that results in good clinical outcomes and a good long-term survivorship. Its biggest drawback seems to be a decrease in post-operative flexion compared to posterior-stabilized TKA, which we think is explained in part by a lesser tolerance for slight technical errors. New tools are available to identify the benefits of this technique and to better understand how to do it: patient-reported outcome scores like the new Knee Society score [16] and the Forgotten Joint Score [17], kinematic analysis devices like the KneeKG™,

biplanar imaging devices like the EOS system™, computer-assisted surgery. It will be interesting to see if these instruments will help render this technique more reliable and make orthopedic surgeons more comfortable to perform it on their patients.

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CLOSING WEDGE VARUS TIBIAL OSTEOTOMIES: SURGICAL TECHNIQUE AND LONG TERM RESULTS

N. JAN, P. CHAMBAT, J.-M. FAYARD

INTRODUCTION

Surgical treatment of painful lateral osteoarthritis for young and high demanding patients still remains controversial. Lateral osteoarthritis may be associated to valgus deformity. Such deformity leads to excessive loading on the lateral compartment and progression of the degenerative changes. By correcting the deformity, varus osteotomy unloads the affected compartment and relieves the pain.

As Puddu *et al.* said: "Which osteotomy for a valgus knee?" [1]. Such procedure can be performed either on the femur and the tibia. Since the first report by Jackson and Waugh in 1961 [2], results of high tibial varus osteotomies (HTVO) have been analysed only in five clinical studies [3, 4, 5, 6, 7]. The authors stated that tibial osteotomy in excessive valgus deformity leads to joint line obliquity, instability and unsuccessful results. Since then, varus osteotomies were more commonly performed on the femoral side.

The aim of our study was to report the long-term results of medial closing wedge high tibial osteotomy and to analyse the complication and revision rate of such procedure.

MATERIALS AND METHODS

A consecutive series is reported of 31 HTVO in 30 patients. All the patients were operated by the same senior surgeon between 1997 and 2011.

Inclusion criteria were symptomatic osteo-arthritis of the lateral compartment of the knee and a minimum of 36 months of follow-up.

Exclusion criteria were HTVO after lateral tibial plateau fracture, chronic ACL deficiency, or overcorrected high tibial valgus osteotomy. Contraindications were Rheumatoid arthritis, preoperative tibiofemoral subluxation, osteo-arthritis of the medial compartment of the knee (Ahlbäck > 1) [8].

Surgical Technique

The mechanical axis of the lower limb was analyzed using bilateral full length standing alignment film. Full weight-bearing antero-posterior views in full extension and at 30° of flexion, lateral but also axial views were performed to evaluate the status of the tibiofemoral and patellofemoral compartment.

Surgery was performed in supine position under general anesthesia and fluoroscopic control with the knee flexed at 90°. Arthroscopy was systematically performed at the beginning of the procedure to assess of cartilage status of the three compartments but also to treat a possible meniscal flap.

The approach was classically anteromedial, starting at the apex of the patella. Hamstring tendons were realeased from their tibial insertion and retractor was placed behind the posterior aspect of the tibia to protect the neurovascular structures. Two parallel K-Wires were introduced from the medial aspect of the tibia to the upper part of the proximal tibiofibular joint (fig. 1A). The superficial layer of the medial collateral ligament was cut and the osteotomy was performed just below the K-Wire (fig. 1B). A second cut was driven few millimeters over the first one (fig. 1C). A lateral hinge should be preserved. Then the K-Wires were removed and a triangular bone wedge was resected (fig. 1D). Primary resection should be as economic as possible to avoid overcorrection. Applying a varus stress on the tibia, the osteotomy was closed. The osteotomy was temporary fixed with a staple (fig. 1E) and the correction was analyzed under fluoroscopy with a rod joining the center of the hip to the center of the ankle (fig. 1F). A normal mechanical axis was aimed. At this step, no varus stress should be applied to avoid lateral collateral ligament tensioning and pseudo-overcorrection (fig. 1G). If the correction was insufficient, an additional bone wedge was removed. When the final correction was reached, the staple was removed and the osteotomy was fixed with a four-hole C-plate or T-plate (fig. 1H).

Postoperatively, the lower limb was immobilized in a functional brace and early rehabilitation was allowed. Patients were non-weight bearing for 45 days then progressive weight bearing during the next two weeks.

Outcome measures

The main purpose of this study was survivorship analysis. In a best case scenario, the end-point was the failure of the osteotomy leading to total knee arthroplasty. In a worst case scenario, the end-point was the date of the knee replacement procedure, or the last review for the unsatisfied patients or the ones lost to follow-up.

Clinical outcomes were analyzed preoperatively and at final follow-up using the Knee Society Score [9]. Activity level using the UCLA score [10] was recorded 3 times: before the symptoms, before the osteotomy, and at the final follow-up. Knee injury and Osteoarthritis Outcome Score (KOOS) was used only for final self-assessment [11]. Complications and subsequent knee surgeries were also recorded since the index procedure.

Radiographic analysis included measurement of the mechanical Medial Proximal Tibial Angle (MPTA), the mechanical Lateral Distal Femoral Angle (mLDFA), the Joint Line Convergent Angle (JLCA), using Paley's method, and the Hip-Knee-Ankle angle (HKA: mechanical tibiofemoral angle) on standardized long-leg standing weight-bearing view [12]. Tibial slope and Caton-Deschamps index were measured on lateral view [13]. Tibiofemoral and patellofemoral osteoarthritis were evaluated according to Ahlbäck and Iwano classifications preoperatively and at final follow-up [8, 14].

Statistical analysis

Statistical significance was set at $p<0.05$. Cumulative survival rate was estimated by Kaplan-Meier analysis. Normally from non-normally distributed data were distinguished by Shapiro-Wilk test. In the first case, after variance equality test, paired Student's *t*-test was used to find a statistical significant change

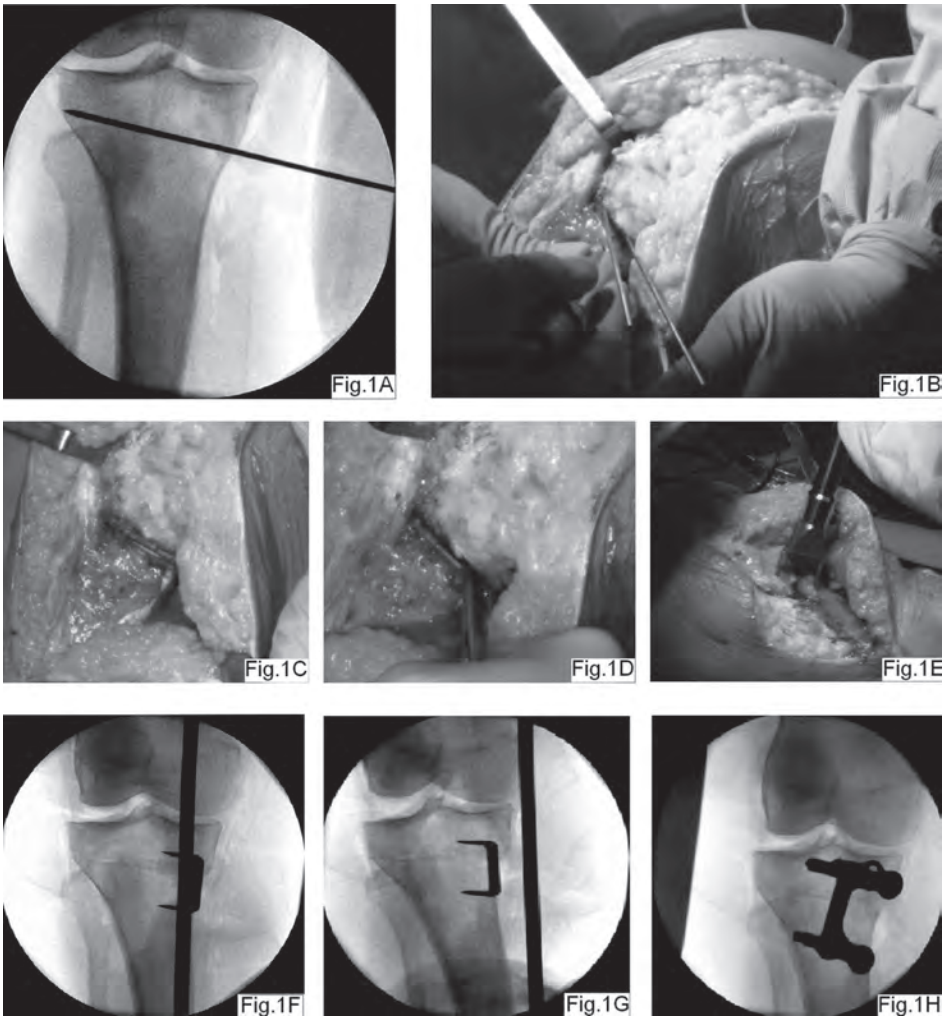

Fig. 1 : Surgical technique

in patient-reported outcomes between final and preoperative values. In the other case, Wilcoxon's test or sign test were performed. Gnumeric (Free Software Foundation, Boston, USA) and "R" (R Foundation for Statical Computing, Vienna, Austria) were used for statistical analyses.

RESULTS

Between 1997 and 2011, 31 HTVO in 30 patients (sex ratio=1) were performed for primary osteoarthritis and were reviewed at mean 12 years of follow-up (range: 3.1 years – 16.6 years).

At the time of index procedure, the mean age was 56 (range 38.8-67.1) years. HTVO concerned 8 left knees and 23 right knees. Seven patients had no previous surgery. Varying degrees of lateral meniscectomies were performed in 23 patients (24 knees) before the index procedure. Among these patients, one has had also a distalization of the tibial tubercle in the same procedure. In different procedures, four patients have had varying degrees of medial meniscectomy and one patient underwent loose-body removal under arthroscopy.

Eighteen lateral meniscectomies, four medial meniscectomies, one loose-body removal and five notchplasties were associated to the HTVO. "T" plate (Tornier©) was used in 24 HTVO and C-plate (Otis SBM©) in 7 HTVO after 2007. No bone graft was required.

Survivorship analysis

Three patients were lost to follow-up. Revision to total knee arthroplasty was performed at the mean time of 10.3 years (range 4.4-15.3) in 9 patients.

In a best-case scenario, with knee replacement as the end-point the cumulative survival rate of the HTVO was 96% (95% CI 0.92 to 1.00) at 5 years, 87% (95% CI 0.80 to 0.94) at 10 years, and 60% (95% CI 0.47 to 0.74) at 15 years (fig. 2).

At the last follow-up, 23 patients were pain relieved and declared they have improved their activity level. Unsatisfied patients (4 cases), patients lost to follow-up (3 cases), patients with/or waiting for knee replacement (11 cases) were considered as failure. In a worst-case scenario, with failure as the end-point, the cumulative survival rate of the HTVO was 87% (95% CI 0.80 to 0.93 at 5 years, 71% (95% CI 0.62 to 0.80) at 10 years and 41% (95% CI 0.30 to 0.52) at 15 years.

Clinical outcomes

At final follow-up, 13 patients could not be included for clinical evauation: one refused, 9 patients underwent knee replacements and 3 were lost to follow up. Finally, 17 patients (18 knees) were available for complete clinical

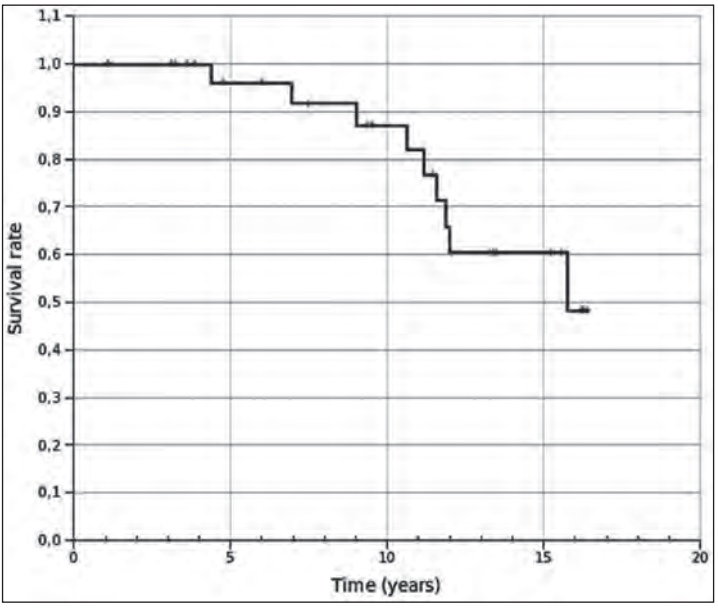

Fig. 2 : Survivorship analysis : best-case scenario

assessment at a mean 10.4 years follow-up (range: 3.1 years – 16.5 years).

The mean Knee Society objective scores improved from 53.4 (range, 14-80) to 72.1 (range, 43-95) (p=0.001). The mean Knee Society function score improved from 78.8 (range, 30-100) to 91.7 (range, 70-100) (p=0.02). The mean pain score (0-50 points) improved from 12.2 (range, 0-30) to 32.8 (range 10-45) ($p < 0.001$).

At the same point, the mean KOOS was 57 (range 20-76), pain: 66 (range 25-94), symptom: 57(range 18 – 82), ADL: 74 (32-96), Sport/rec: 30 (0-65), QOL: 57 (19-94).

Patients' activity levels outcomes are recorded table 1. A significant difference was found between pre and postoperative values.

Radiographic outcomes

A significant difference was found between the mean preoperative and postoperative values of mechanical tibiofemoral angle (HKA), MPTA, and tibial slope (Table 2). No significant difference was found between the preoperative Ahlbäck or Iwano grade and the radiographic assessment of osteoarthritis at the final follow-up (Table 3). Preoperatively, all patients but 3 had a normal mechanical axis or a valgus deformity. At final follow-up, all the patients but one had a varus deformity or normal mechanical axis. Postoperative varus deformity of more than 5° was recorded only in 3 patients. All the patients but two had a postoperative joint line obliquity under 10°.

Complications and subsequent procedure

Hardware removal was performed in 6 patients at a mean 1.7 years follow-up. At the same time, two patients underwent arthroscopies for persistent painful swelling. Partial lateral and medial meniscectomies were performed and relieved the pain. No major complications such as infection, thromboembolic events, intra-articular fractures, neurovascular complications, delayed or non-union were recorded in the study.

Table 1 : Patients' activity levels outcomes

UCLA	asymptomatic	Preoperative	final
Median	9	6	8
Range	4-10	4-9	4-9
N	27	26	18
	P<0.001		
		P<0.001	
	P=0.001		

Table 2 : Mechanical axes and index

	Preoperative		Post operative		p
	Mean	Range	Mean	Range	
HKA	184	178-188	178	170-186	<0.001
mLDFA	86	83-89	86	81-89	0.131
MPTA	90	83-94	83	77-89	<0.001
Tibial slope	83	80-87	86	80-90	<0.001
Caton's index	0.9	0.7-1.3	0.9	0.4-1.4	0.375

Table 3 : Radiographic assessment of osteoarthritis

	Preoperative		Final follow-up		Sign test
	Median	Range	Median	Range	p
	Ahlbäck classification				
Lateral tibiofemoral	2	1-3	3	2-4	0,387
Medial tibiofemoral	0	0-1	0	0-2	0,63
	Iwano Cassification				
Femoropatellar	1	0-3	1	0-3	0,113

In 2 patients, joint line obliquity of more than 10° was recorded. One patient had clinical improvement (function score +10; knee score +29) at 3.6 years follow-up. No tibiofemoral instability was recorded. The second patient presented recurrent pain with tibiofemoral instabilty one year after the index procedure. He underwent knee replacement at 4.4 years follow-up.

Prognostic factors

Using independent T test, the mean time between lateral meniscectomy and the osteotomy seemed to be significantly different ($p<0,001$) between the failure group (8.5 years) and success group (24.9 years) as defined in the worst case scenario.

No significant difference was found between the failure group and success group for MPTA and mLDFA. But 2 early failures occurred in patient with a femur valga and there was a greater proportion of femur valga (mLDFA < 85°) than tibia valga (MPTA>90°) in the failure group.

DISCUSSION

There is low evidence in literature about varus osteotomies for valgus arthritic knees and most of the studies concern distal femoral varus osteotomies (DFVO) [15]. Allthough these series were heterogeneous in term of surgical technique, clinical assessment and follow-up, all of them reported good results with significant improvement of the clinical and functional scores. But functional outcomes and survival rate tend to decrease after ten years follow-up. Our long term study showed a significant improvement of IKS knee and function scores but also of the UCLA activity score at a mean 10 years follow-up after closing wedge HTVO.

Concerning survivorship of DFVO, revision rate by knee arthroplasty ranged between 10 and 37% at 10 years follow-up [16, 17]. In the present study of HTVO, we reported a revision rate of 13% at 10 years follow-up.

If lateral unicondylar arthroplasty seems to be a possible option with good long-term functional outcomes, younger patients are more exposed to early failure. A recent study of the National Joint Registry reported 5% revision rate at five years follow-up. This revision rate increased over 10% for patients under 50 years old [18]. By sparing bone stock and allowing good long-term functional results, osteotomy is a suitable option for young and/or active patient suffering from lateral knee osteoarthritis.

However, several authors reported a high rate of complications and subsequent surgeries after antivalgus osteotomies. In the earliest reports of closing wedge HTVO, instability, loss of correction, early degeneration of the medial compartment and poor results were reported.

But this procedure was performed even in large valgus deformities and an overcorrection was aimed leading to joint obliquity and shear stresses of the femur on the tibia [2, 3, 4, 6]. In a series of opening wedge HTVO Marti *et al.* reported 9% of common fibular nerve palsy [6]. Thanks to these findings, more recent studies were mainly focused on DFVO.

Nevertheless, closing or opening wedge DFVO have had a complication rate of 63% including stiffness, non or delayed union and hardware failure [19]. In a series of lateral opening wedge, Jacobi et al reported 86% of impingement between the plate and the iliotibial band [20].

In our series, we did not record any major complication such as stiffness, non or delayed union and nerve injury. Complication rate was 23% (7 cases/31) including hardware removal (4 cases), hardware removal with partial menisectomy (2 cases) and one symptomatic joint line obliquity requiring early total knee replacement.

If both femoral and tibial osteotomies provide good long term functional results, the final alignment after such procedure is still controversial. In the early series of HTVO, an over correction was aimed leading to overloading of the medial compartment and early failure [1, 5]. Thanks to these findings, some authors stated that ideal correction after osteotomy for valgus knees should be a normal mechanical alignment or a slight hypo correction [1, 5]. There is no equivalence for the "Fujisawa Point" for varus osteotomy [21]. A loading point just medial to the medial tibial spine was also proposed [7]. In our series, normal alignment was aimed for symptomatic valgus knees. In case of normal mechanical axis, the goal was a varus axis under 5°.

Thus, the type of the osteotomy (HTVO or DFVO) depends on the location of the valgus deformity [6]. According to Hoffman *and al.*, genu valgum is located on the femur in 22%, in the tibia in 45% and both in 33% [22]. Alghamdi *and al* also recorded 53% of tibia valga in ostearthritic valgus knees [23]. Paley and Tetsworth described a Malalignment Test (MAT) to analyse the origin of the deformities of the limb [12]. Normal values for tibial (MPTA) and femoral (mLDFA) mechanical axis are between 85° and 90°. Normal value for JLCA is between 0° and 3°. A JLCA of more than 3° is associated with medial collateral ligament laxity or bone loss on the lateral compartment. The importance of the joint laxity could be evaluated by monopodal and/or bipodal stance views and bony deformity could be evaluated by non weight bearing views. In case of medial collateral ligament laxity, some authors proposed MCL thightening [3, 24]. In our series, all patients had a JLCA between 0° and 3° preoperatively.

According to Coventry a*nd al* and Shoji *and al.*, DFVO should be done when the valgus deformity exceeds 6° or if the planned postoperative joint line obliquity exceeds 10°. To be more precise, femoral contribution in valgus deformity should be considered when the mechanical femoral angle is less than 84°. In our series, early failure occurred twice when the valgus deformity was on the femur with a normal or varus tibial deformity.

HTVO may lead joint line obliquity, but DFVO is efficient only in extension, not in flexion and leads to internal rotation in flexion. On the opposite, HTVO is efficient both in flexion and in extension [5].

As a conclusion, closing wedge HTVO for lateral osteoarthritis provides good long term functional and clinical results with a low complication and revision rate. However, conditions for a good result are a preoperative femoral valgus deformity under 6°, a normal postoperative axis, a postoperative joint line obliquity under 10°. If the femur valga exceeds 6°, femoral or combined tibial and femoral osteotomies should be considered.

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THE EFFECT OF LATERAL OPENING WEDGE DISTAL FEMORAL OSTEOTOMY ON LEG LENGTH

V. VILLA, A. MADELAINE, T. LORDING, S. LUSTIG, E. SERVIEN, P. NEYRET

INTRODUCTION

Varising distal femoral osteotomy is a well-described treatment for lateral compartment arthrosis in the young, active patient. Distal femoral varising osteotomy may be performed using a lateral opening wedge or medial closing wedge technique [1-2-3-4]. The most commonly described technique is the medial closing wedge [5-11]. In our center, the preferred method is the lateral opening wedge. Little literature exists regarding the results and complications of this technique [12-15]. This treatment may potentially alter the length of the lower limb. The objective of this study is to quantify the change in leg length following lateral opening wedge distal femoral osteotomy using a blade plate.

MATERIAL AND METHOD

Between January 1998 and December 2011, we treated twenty-seven patients (29 knees) with symptomatic genu valgum with signs of lateral compartment osteoarthritis, with or without associated lateral patello-femoral degenerative changes as seen on standard radiographs. All patients underwent lateral opening wedge distal femoral osteotomy. Two patients underwent bilateral procedures. We excluded patients who underwent combined high tibial osteotomy or femoral rotational correction.

The mean age was 44.4 years. We used the newly validated *Knee Society Score* (KSS), French version. This measure gives an objective score based on symptoms, range of movement and axis, and a subjective score based on knee function and patient satisfaction [16]. Patients were reviewed two, six and twelve months post-operatively. The mean follow-up was 80.2 months (23.1-198.7). The mean deformity in the twenty-nine knees, as measured by the femoro-tibial mechanical axis (mFTA) [17], was 187.8° (183.0°-197.0°).

The aim of the osteotomy was to correct the axis of the lower limb to a neutral alignment of between 0° and 3° of varus, with a preference for slight over-correction rather than under-correction. Careful pre-operative planning was used to determine the degree of correction and magnitude of opening of the osteotomy.

A lateral incision, 15 to 18cm in length, was used, and the bone approached in front of the iliotibial band but behind the vastus lateralis.

Two guide wires were introduced using artery forceps: one across the femoro-tibial joint and one across the patello-femoral joint. These were used to guide the orientation of the blade plate and reduce the need for fluoroscopic control.

A horizontal osteotomy was used, at the superior border of the lateral trochlea. The

blade osteotome was introduced into the epiphysis for optimal fixation, with an entry point proximal and anterior to the origin of the lateral collateral ligament.

The optimal obliquity of the blade in relation to the joint line depends on the location of the deformity and the magnitude of the desired correction.

The osteotomy was performed using a saw, at least 25mm from the entry point for the blade plate to ensure an adequate cortical bridge. The blade plate was then introduced. The medial cortex was weakened by perforation with a guide wire, taking care to maintain cortical continuity.

The osteotomy was opened using two or more Lambotte osteotomes, whilst the blade plate was impacted. The opening and impaction was continued until the plate was in contact with the lateral cortex of the femur. Fixation was then completed in the diaphysis using bicortical 4.5mm screws above the level of the osteotomy. The osteotomy was grafted using cortico-cancellous autograft from the ipsilateral iliac crest.

Operative data were collected, and pre- and post-operative alignment and leg length were measured.

RESULTS

The mean osteotomy opening was 8.3° (5°-13°). The femoro-tibial mechanical axis (mFTA) was improved significantly, from 187.8° (183.0°-197.0°) to 180.4° (176.0°-186.0°) post-operatively ($p<0.001$), without loss of correction over the follow-up period (fig. 1 et 2). The pre-operative leg length discrepancy was -0.7cm, compared to -0.6cm post-operatively, which was not significant.

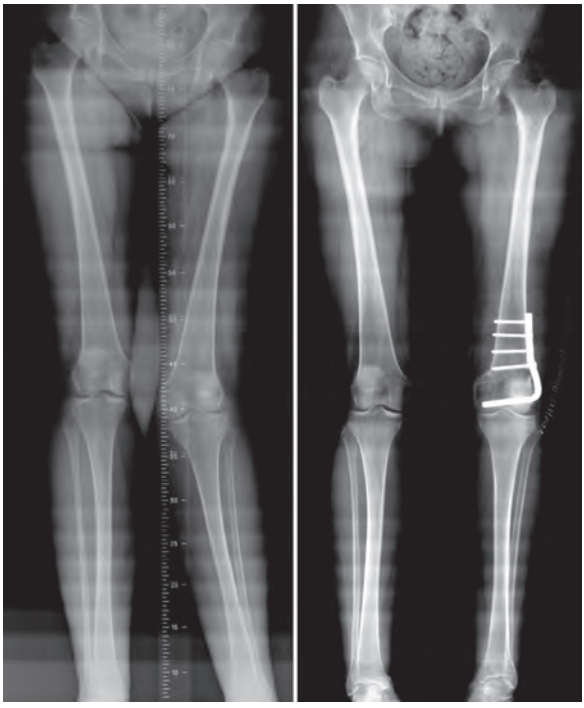


Fig. 1: Pre and postoperative long leg views of a 40 year old patient with idiopathic genu valgum. mFTA improved from 197° to 178° on the immediate postoperative long leg view.

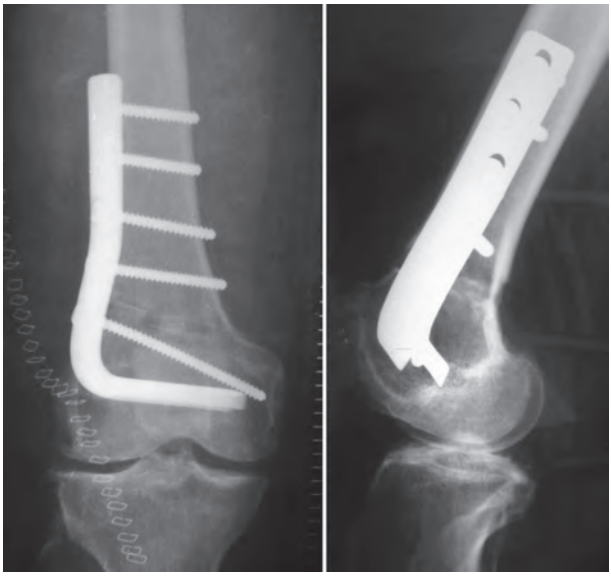
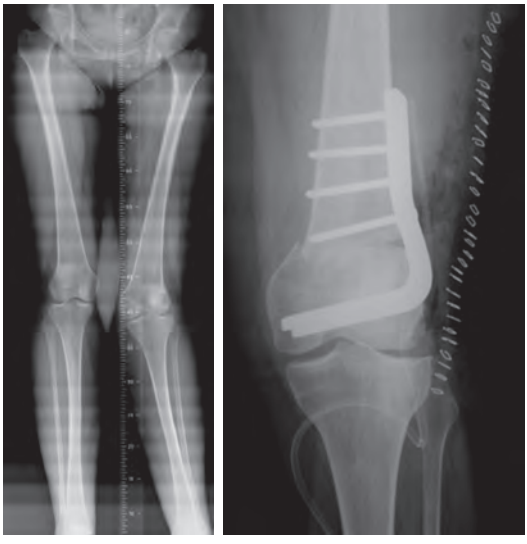


Fig. 2: Postoperative radiographs of a 50 year old patient who presented with an idiopathic genu valgum of 188°.

The *Knee Society Score* (KSS) functional component improved from 50.4 (26.0-80.0) to 68.5 (1.0-97.0), though this did not reach statistical significance (p=0.12). 25 patients were satisfied or very satisfied, and 4 were unsatisfied. There was one loss of fixation (fig. 3), two delayed or non-unions and one case of post-operative stiffness. There were five revisions to arthroplasty for disease progression at mean time of 166.6 months post-operatively. The probability of survival at 60 months was 91.4% [95% confidence interval 100%-74.9%] with end-point of revision to total knee arthroplasty and 87.6% [95% confidence interval 100%-74.1%] for revision for complications (fig. 4).



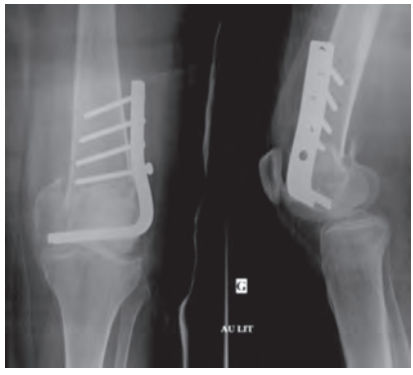


Fig. 3: 40 year old patient with multiple sclerosis with loss of fixation of the osteotomy at day 20 postoperatively: Preoperative long leg views with mFTA of 197°, immediate postoperative radiograph, fracture at day 20. The medial hinge fractured secondary to poor bone quality.

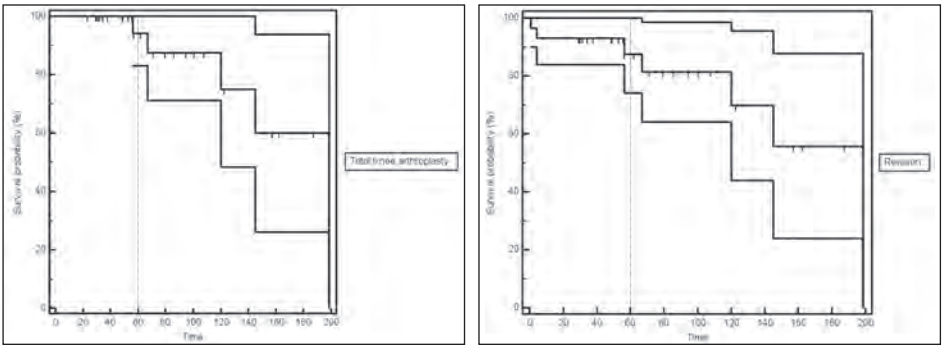


Fig. 4: Kaplan-Meier survival analysis curves with 95% confidence interval.

DISCUSSION

Lateral opening wedge varising distal femoral osteotomy, performed for symptomatic genu valgum, has no effect on leg length.

The technique allows satisfactory angular correction, which is stable over the medium term. Subjective results are good with a high rate of patient satisfaction. The rate of significant post-operative complications was low, with only two early revisions. We do not consider removal of internal fixation to be a complication. There was only two case of delayed or non union of the osteotomy. The case of hinge fracture with loss of fixation occurred in a special case with poor bone quality. This is the largest series of patients undergoing this intervention to date. A review of the literature is summarized in table 1 [6-7-8-9-10-13-15-18-19].

No previous study has analyzed change in leg length after distal femoral osteotomy, by either lateral opening or medial closing wedge techniques. Using the lateral opening wedge technique, we have been able to restore a normal mechanical axis.

The blade plate seems to be a good method of internal fixation but with a non insignificant rate of non union. In our study, delayed or non union occurred in post-traumatic cases with poor bone quality. To avoid such complications, technical improvement of the method of fixation is needed. The non-weight bearing period may be an important factor in delayed union, however, there is no consensus in the literature regarding the optimum postoperative rehabilitation [12].

This study involved a homogenous group of patients, operated using the same technique and rehabilitation protocol. Some limitations of this study, however, should be noted. The duration of follow-up in our study is limited compared with similar studies due to our limited indications. However, this is the largest series of patients undergoing this intervention to date.

We used the new KSS in this study. It is important to note that this version includes more items than previously, which may result in an inferior score. Deformity correction in varising distal femoral osteotomy predominantly affects the knee in extension. The effect is clear in long leg views but unknown in Rosenberg or flexion views. This is not reported in the literature nor examined in this study. Further study is recommended to examine the effect on the joint line in flexion.

Table 1: Literature review comparing follow-up, pre and postoperative axis and LLD and complications

Authors	Year	Cases	Mean follow -up (months)	Mean pre-operative axis (°)	Mean post -operative axis (°)	LLD pre/post	Complications
Lateral opening wedge distal femoral osteotomy							
Zarrouk et al. [13]	2009	22	90	194.5	-	-	-
Jacobi et al. [15]	2011	14	45	-	-	-	1
Dewilde et al. [14]	2013	19	68	195.3	178.7	-	1
Saithna et al. 12]	2013	21	54	-	-	-	6
Our Study	**2014**	**29**	**80**	**187,8**	**180,4**	**-0.7/-0.6**	**4**
Medial closing wedge distal femoral osteotomy							
Edgerton et al. [6]	1989	24	60	198	181	-	17
Finkelstein et al. [5]	1996	24	133	-	-	-	4
Aglietti and Menchetti [11]	2000	18	108	197,5	186	-	0
Marin Morales et al. [10]	2000	19	78	196	181	-	1
Wang et al. [9]	2005	30	99	198,2	181,2	-	4
Backstein et al. [7]	2007	40	123	191,6	178,8	-	-
Kosashvili et al. [8]	2010	33	181	-	-	-	-
Opening or closing wedge distal femoral osteotomy							
Zilber et al. [18]	2004	11	126	193	182	-	3
Varising tibial osteotomy							
Marti et al. [19]	2001	36	132	191,6	185,8	-	4
Collins et al. [20]	2013	24	54	182,4	177,4	-	3

CONCLUSION

Lateral opening wedge varising distal femoral osteotomy, using a blade plate and performed for symptomatic genu valgum, has no effect on leg length. This technique allows good correction of the axis of the lower limb, however, the complication rate is not insignificant and the procedure should be reserved actually for young, active patients with significant symptoms.

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LATERAL UNICOMPARTMENT KNEE ARTHROPLASTY (UKA): TECHNICAL CHOICE, CHOICE OF IMPLANT AND RESULTS

R. BADET, S. PIEDADE

In the 1950s, Mckeever presented the concept of unicompartmental knee resurfacing, the goal of this procedure is to replace only the damaged tibiofemoral compartment. However, it was only in the 70s that the development of the unicompartmental knee arthroplasty (UKA) actually started.

The literature has demonstrated very good results after UKA of the lateral knee compartment (Table 1). In our experience, 70% of patients had no knee complaints, with mean knee flexion of 133° and Kaplan-Meier survival curve of 97% rate at 10-years follow-up. However, it is extremely important to identify and respect the criteria and principles related to the surgical indication, knee balance as well as the correct positioning of the implants.

PATIENT-RELATED FACTORS (MAJOR RULES)

Stage of knee osteoarthritis

In cases of the irreducible and severe lateral knee osteoarthritis (which are commonly associated to peripheral ligament anomalies), the lateral unicompartmental knee replacement is contra-indicated.

In our experience, the stage of knee osteo-arthritis has influenced the surgical outcomes. the knee score and the function score were more bad if the stage of knee osteoarthritis was more high.

	n	Survival	Clinical results
Berg 2005	66 (Miller Galante)	98% at 10 years	80% excellent results
Tabor 2005	100 (Marmor)	90% at 10 years	knee score 91 functional score 77
Price 2005	114 (Oxford)	94% at 10 years	91% excellent or good results
Pennington 2006	29 (Miller Galante)		100% excellent or good results
Amin 2006	54 (Oxford)	88% at 5 years	knee score 82 functional score 85
Kobayshi 2001	30 (Mamor, Oxford, Omnifit)	96.4% at 10 years	knee score 82 functional score 68.4

CORONAL KNEE MALALIGNMENT AND CORRECTION

The objectives of UKA is to correct bone wear and restore the patient's original alignment, however, with no correction of the knee constitutional deformity. Therefore, the axis correction is individual and, for each patient a residual valgus deformity will be predicted after than the bone wear had been compensated. Hence, the final knee alignment should be in valgus for the lateral UKA and in varus for medial UKA. On the other hand, patients with no malalignment will have a final knee alignment of 180°.

Thus, the surgical procedure should leave persist a hypocorrection, with a residual knee deformity. In the cases of important constitutional deformities (higher than 10°), particularly when the knee is fixed, the UKA should be contra-indicated.

LIGAMENT STATUS: CENTRAL PIVOT AND PERIPHERAL LIGAMENTS

UKA : no lesion of cruciates ligaments and no lésion of peripherals ligaments. The cruciates and peripheral ligaments should be intact and an anterior cruciate ligament tear is a classical contra-indication to the UKA. Moreover, the presence of medial laxity with a medial retraction (which could attest to medial collateral ligament insufficiency secondary to distension or to rupture) presents a contra-indication to UKA because it has an important risk of failure.

In clinical practice, the non-compliance of these major rules could lead to failures and to a bad results.

PATIENT-RELATED FACTORS (MINOR RULES)

Age: Currently, the UKR has an ideal indication to elderly patients (> 70 years old).

Level of activity: It is usually associated to age. Classically, the UKA has been indicated for patients with low level of activity.

Weight: Many authors have recommended a BMI < 30, but, others studies have found no influence of the patient´s weight on the outcomes.

The remodeling knee osteoarthritis with no medial tibiofemoral and patelofemoral compartment narrowing could influence the outcomes of the lateral UKA.

In practice, each minor rules alone does not present a real contra-indication to this procedure.

It is very important to integrate these data in a overall context. The goal of the integration of these data should be to limited the possible risk of failure secondary to wear and loosening. Hence, the ideal patient should be 70-year old or more, no overweight and low level of activity.

TECHNICAL FACTORS (COMPONENTS)

Femoral component

The complexity of the anatomy of the femoral condyles (Fick's multicenter model or Frain's spiral logarithmic monocentric model) clearly seen on the knee lateral view where the design of the implant is formed by two circles: one large anterior curve, the other, smaller posterior radius.

In the frontal plane, the radius of curvature is generally convex, symmetric and sufficiently wide to allow adequate stress distribution on the tibial component, reducing the **risk of excessive loading**.

Some laboratories have developed asymmetrical medial/lateral condyles which purpose is to avoid the patellofemoral conflict. However, the major challenging is the need of more instrumental boxes.

Classically, two concepts were described: femoral prosthesis performed by "resection" ("cut") and by "resurfacing".

The term "resurfacing" or "resection" in the UKA procedure defines the gesture to be done on the anterior and distal femoral condyle, since a cut is usually done on the posterior femoral condyle which is without wear.

Systems of resection ("cut")

The UKA critics have emphasized that the sacrifice of subcondral bone could be a factor of prosthesis loosening and also, a factor of bone loss. These systems seek to ensure a distal femoral cut perpendicular to the mechanical axis of the femur performed by intra or extramedullary guides.

Although, the intramedullary guide is more accurate than extramedullary ones, the classic morbidity related to the catheterism of femoral diaphyis (fat embolism and cortical bone damage) is a disadvantage and hence, the mini-invasive approach is considered.

On the other hand, the extramedullary guides have no additional morbidity, but they are less accurate than intramedullary ones.

Systems of resurfacing

These systems are well-matched to the concept of mini-invasive surgery. The main advantages of these systems are preservation of the subchondral bone, which allow solid fixation to the prosthesis there are no guide and the ancillary is compact.

Usually, one or two pegs or sagittal fin are used to the femoral component fixation.

Certain systems called "resurfacing" perform a gradual and variable drilling of the femoral condyle according to the extension gap; it could lead to bone loss such that they are closer to the bottom in the system of resection than resurfacing.

However, both systems ("resection" or "resurfacing" UKR) have their indication in lateral UKR.

In our point of view, the origin of the tibial and femoral deformity guides this decision. Therefore, a resurfacing UKR to build the lateral femoral condyle has been indicated when hypoplasia of the lateral femoral condyle exists. However, if the lateral femoral condyle is normal and the valgus is on the tibial side, the resection UKR should be performed, because resurfacing UKR could lead to hyperstructure of femoral condyle, tibial overcut and lower joint line which is source of pain and worse functional results.

Tibial component

The main causes of UKA failure due to wearing and loosening of the tibial plateau are well known.

The thickness of the polyethylene

It plays an important role in case of wear of polyethylene caused by flow or creep, where sustained stress produces the polyethylene deformation, which is less important with a thicker polyethylene. In the UKA, a high density polyethylene can be used. A minimum thickness of 6mm is recommended to limit the risk of wearing by creep with no metal back and 9mm thickness, in case of metal bac.

Tibial fixation

Fixed bearing

2 types should be distinguished:
Full polyethylene-piece has the advantage of avoiding the interfaces. An non progressive radiolucent line on the tibia is common, but clinical results are very satisfactory.

Tibial metal back imposes the need of 9mm polyethylene height. The fixation is done by cement or by screws (which could be a cause of loosening secondary to granulomas along the screws).

Certain authors have criticized these systems because they could create a peak of stress, which could explaining some residual pain in postoperative outcomes of UKA.

Mobile bearing

In 1974, Goodfellow has developed the concept of mobile bearing aiming at reducing the stress and wearing of the polyethylene. In this context, the polyethylene implant is necessarily concave with two congruent jaws (lips). This type of implant is not suitable to lateral femorotibial compartment because its hypermobility could lead to a higher failure rates secondary of polyethylene dislocation (10%).

Size and shape of tibial insert

Minimal access approach associated to particularities of local anatomy has justified the development of instruments well-matched for proper evaluation of the depth and wide of tibia. An Unsuitable implants could explain some pain produced by the conflict between implant and soft tissues.

Technical factors: surgical technique

Patient positioning and surgical approach (evaluation of ligament and articular cartilage status).

The patient is positioned supine, knee flexed at 90°. To mobilize the knee in all range of motion.

A lateral parapatellar approach is performed extending from the superior pole of the patella to 2 to 3cm below the joint line (fig. 1A to 1C). The objective is to minimize invasive procedures and consequently, promote accelerated postoperative functional recovery. In addition, whenever it is possible, the incision across the quadriceps tendon as well the patellar eversion should be avoided (fig. 1D).

Careful evaluation of articular cartilage on the patellofemoral and femorotibial compartments and ACL status must be done.

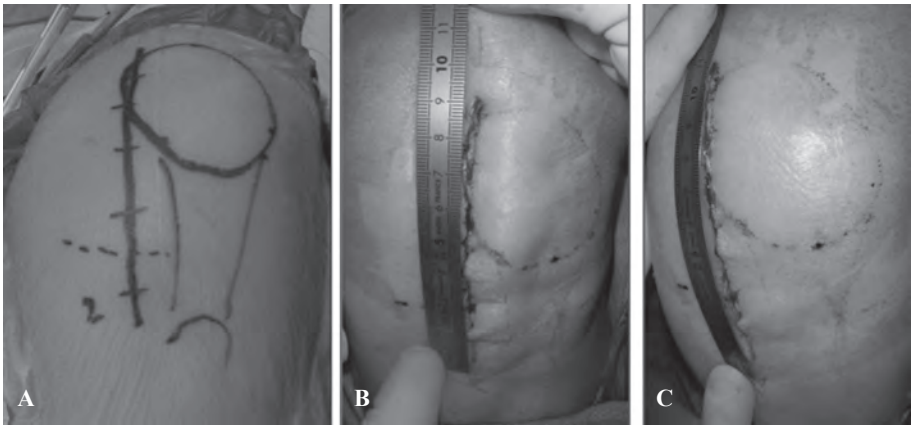


Fig. 1A at 1C: R Knee - Skin incision para patellar lateral approach: top of the patella to 2-3cms below the joint line. 9cm extended knee 11cm flexion knee.

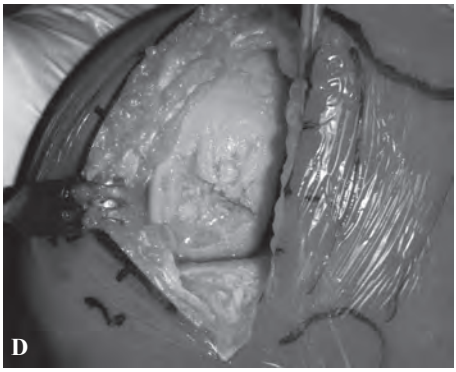


Fig. 1D: R Knee - Good exposition without patella eversion and without quadriceps incision.

Ligament balance

The principle of the UKR is to "slide" the implant prosthesis into the ligamentous envelope of the knee, which will fill the spaces created by bone cuts (fig. 2).

Only loss bone space by wear must be corrected (leaving a small hypocorrection).

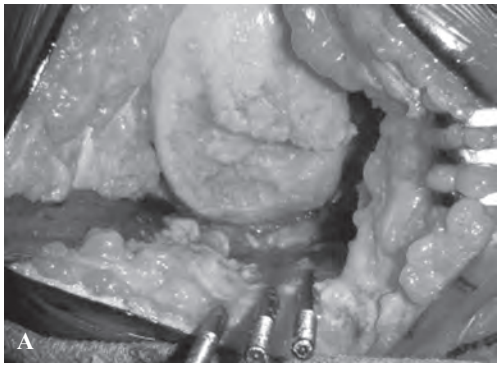
Classically, during the UKR procedure, the ligament releases are forbidden. However, different scenarios could be presented:

- *In case of reducible deformity*, ligament release is non indicated. A subperiosteal release of the capsule could be done.
- *In case of partially reducible deformity* (small ligament retraction) a limited well controlled release can carefully done to avoid an overcorrection by unilateral ligament elongation and consequently a increase of space (that must be filled by the increase of the thikness of the polyethylène of UKR).

Tibial cut (fig. 3A and 3B)

Different cases can be present in the lateral femorotibial osteoarthritis :

• Constitutional valgus knee : the originated of the valgus is on the femoral side, which is usually produced by hypoplasia of the lateral femoral condyle.
If the lateral femoral condyle (hypoplasia) is the line of reference to define the height of tibial cut, it will correct the femoral deformity with a increasing of the tibial polyetilene thickness.
If the thickness of a femoral component is fixe it could promote a partial or total correction of the deformity (by femoral component thickness). On the other hand, when the deformity is severe it could lead to:



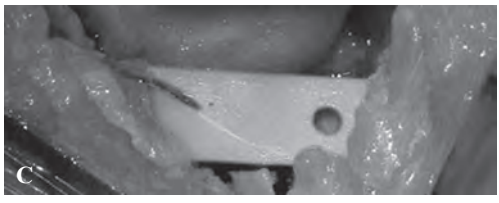


Fig. 2A at 2C - The goal of the UNI is to adapt the frontal deformity of the knee. The prosthesis must correct the wear deformity of the tibia without changing the envelope ligament.

- polyethylene oversize and consequently, an elevation of joint line;
- a persistent residual valgus deformity.

In such cases, we advise to use a resurfacing UKR, because the thicknesses of the femoral components vary, which help reconstruct the lateral condyle and to restore to the adequate level of the joint line (fig. 3C to 3E).

- After a fracture or a depression of the lateral tibial plateau the origin of the valgus knee is on the tibial side. The deformity and the wear has been originated on the tibia and lateral condyle which is "normal or with mild wear" could be a reference to perform the tibial cut with no risk of malpositioning or oversizing of the tibial plateau component.
  In theses cases there is a risk of hypercorrection related to the thickness of the femoral component and a resection prosthesis ("cut") UKR should be performed.

- In case of lateral femorotibial osteoarthritis secondary to meniscetomy, the surgeon must bear in mind that the origin of the valgus deformity (femur or tibia) takes an important role and should guide the surgical strategy.

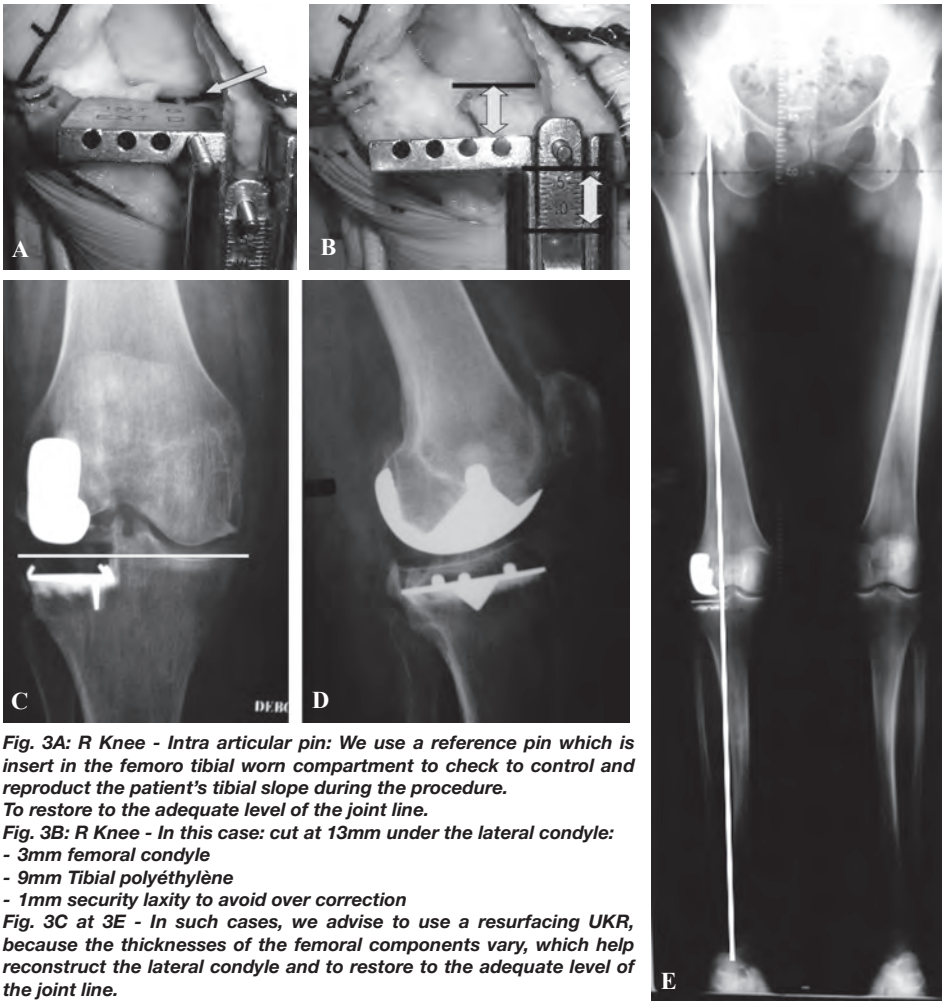


Fig. 3A: R Knee - Intra articular pin: We use a reference pin which is insert in the femoro tibial worn compartment to check to control and reproduct the patient's tibial slope during the procedure.
To restore to the adequate level of the joint line.
Fig. 3B: R Knee - In this case: cut at 13mm under the lateral condyle:
- 3mm femoral condyle
- 9mm Tibial polyéthylène
- 1mm security laxity to avoid over correction
Fig. 3C at 3E - In such cases, we advise to use a resurfacing UKR, because the thicknesses of the femoral components vary, which help reconstruct the lateral condyle and to restore to the adequate level of the joint line.

Tibial Slope and tibial cut

Some systems have incorporate a fixed tibial slope, while others promote an adaptation to the patient's tibial slope (constitutional tibial slope, ACL fragility) in each case.

It should keep in mind that UKA is adapted to the knee with no modification to ligamentous envelope. It is important to adapt the tibial slope of the prosthesis to the tibial slope of the patient. In these case it is very important to use a system with a variable valor of the tibial slope. We use a reference pin which is insert in the femoro tibial worn compartment to check to control and reproduct the patient's tibial slope during the procedure (fig. 3A).

Coronal plane and tibial cut

The goal of the UNI is to adapt the frontal deformity of the knee.

The prosthesis must correct the wear deformity of the tibia without changing the envelope ligament and must keep a slight hypo correction.

This necessarily requires to adapt the frontal cut of the tibial cut at each case using a extramedullary reference system (the intramedullary reference systems being prohibited within the constraints of the surgical approach and ACL respect).

Choise of the tibial implant

Whatever the type of prosthesis, the implant should not overflow the tibia bone. The tibial implant should be fixed (mobile platforms are to be inadvisable in the external UNI because of the risk of polyethylene dislocation).

Femoral Cut

It requires the use of specific tool who are positionned in inter-condylar notch to tract the patella.

The femoral preparation is specific depending on whether if it is a resurfacing prosthesis or if it is cutting prosthesis.

Do not resect the external osteophytes before a good positionning of the condylar implant.

Femoral implant positioning (fig. 4a-4f)

The femoral implant must be positioned with a control of the position in all planes:

- *In the frontal plane* we recommend a perpendicular position of the femoral implant relative of the tibial plane (with 90° knee flexion). This may result a position of the condylar implant different than the condyle axis (fig. 4a 4b), in particular on the lateral condyle where the condylar implant can be positionned on the latéral osteophytes.
- *In the medio-lateral plane:* it is very important to avoid conflict with the tibial spine in positionant the femoral condyle as close to the middle of the condyle sometimes on the lateral edge of the lateral condyle.
- *In the sagittal plane:* it is very important to avoid "camber of condyle" which can lead punctiform or a linear constraint of the femoral implant on the tibial plateau, source of polyethylene wear and degradation (delamination and creep).

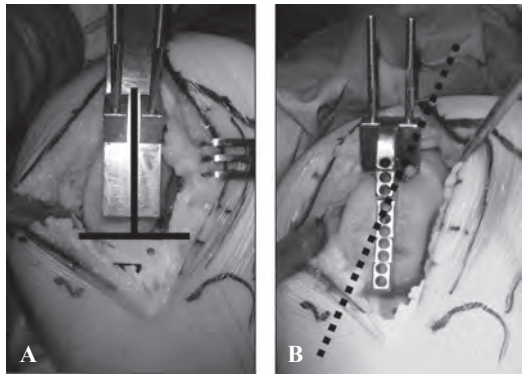


Fig. 4A and 4B - In the frontal plane we recommend a perpendicular position of the femoral implant relative of the tibial plane (with 90° knee flexion). This may result a position of the condylar implant different than the condyle axis, in particular on the lateral condyle where the condylar implant can be positionned on the latéral osteophytes.

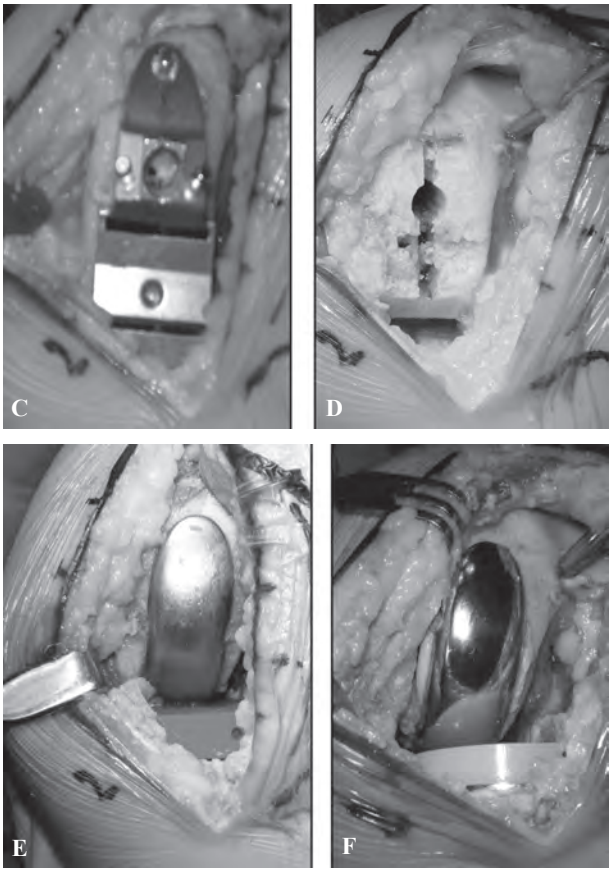


Fig. 4C at 4F - The femoral implant must be positioned with a control of the position in all planes:
- ***In the medio-lateral plane: it is very important to avoid conflict with the tibial spine in positionant the femoral condyle as close to the middle of the condyle sometimes on the lateral edge of the lateral condyle.***
- ***In the sagittal plane: it is very important to avoid "camber of condyle" which can lead punctiform or a linear constraint of the femoral implant on the tibial plateau, source of polyethylene wear and degradation (delamination and creep).***

Choice of femoral implant

Whatever the type of prosthesis it is very important to be sure that the femoral implant doesn't be:
- Too large to avoid an impingement in front of the trochlea, causing conflict with the patella (which is easily controllable fig. 5 a, b).
- Undersize : it must cover correctly the posterior condyle (fig. 5 c,d).

Trial implants and final implants

The implants must allow a filling of the flexion gap and extension gap without lateral collateral ligament tension. The goal in the end of surgery is to have a small security laxity (of 2 to 3mm with stress).

Without ligament release, this small laxity is a good indicator of the absence of overcorrection in frontal plane (fig. 6).

In the External UNI the result than we can hope for our patients is generally very good.

Nevertheless a careful selection of patients and a adapted technicals choices appear decisive to obtain a optimal clinical and radiological outcome.

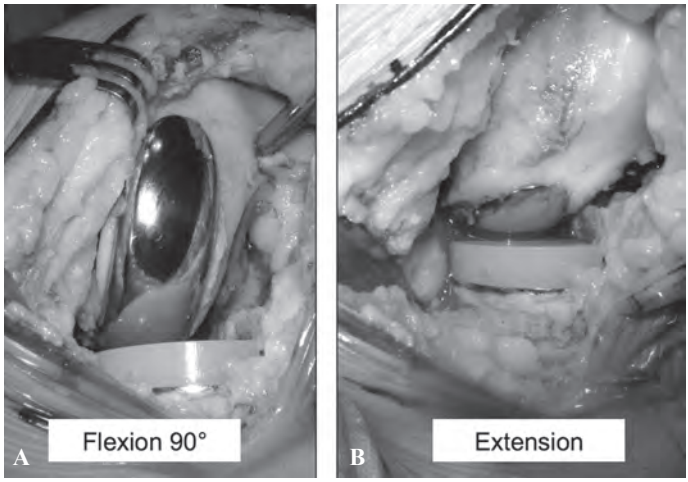


Fig. 5A and 5B - The femoral implant doesn't be too large to avoid an impingement in front of the trochlea, causing conflict with the patella which is easily controllable.

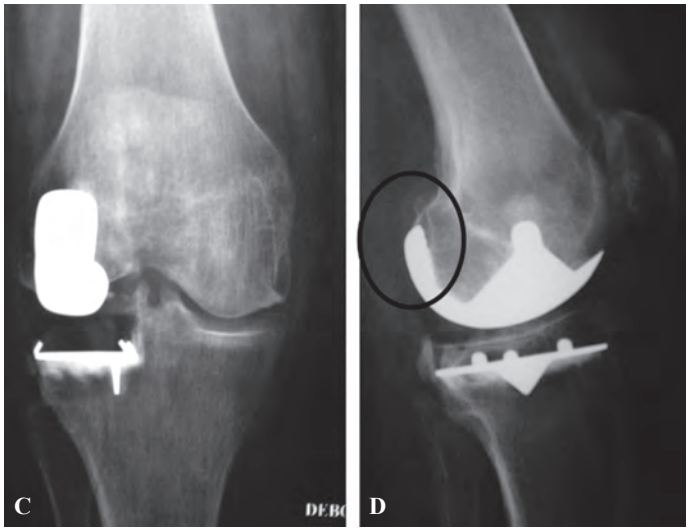


Fig. 5C and 5D - The femoral implant doesn't be Undersize : it must cover correctly the posterior condyle.

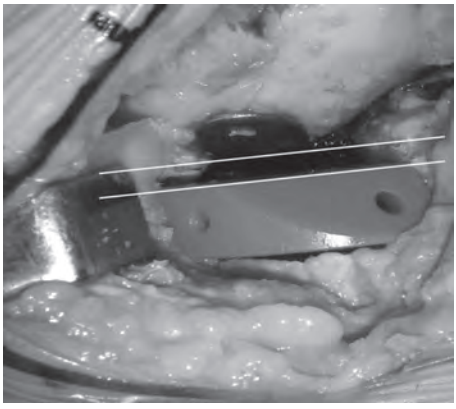


Fig. 6 - The goal in the end of surgery is to have a small security laxity (of 2 to 3mm with stress). Without ligament release, this small laxity is a good indicator of the absence of overcorrection in frontal plane.

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CUSTOM LATERAL UKA

W. FITZ

The lateral tibiofemoral joint does not have the same geometry as the medial. The shape and geometry of the femoral and tibial condyles are different compared to the medial tibiofemoral joint [1-3] (Table 1) and challenge our current practice to use a medial left off-the-shelf implant for the right lateral side and vice versa. The lateral femoral condyle is wider and flatter compared to the medial condyle. The anterior radius of the lateral J-curve is almost twice the anterior radius of the medial condyle (fig. 1) [1]. The width of the lateral condyle is much wider in extension but narrower posteriorly (fig. 2). The lateral condyle is not as curved as the medial condyle and is shorter (fig. 3). Most current off-the-shelf (OTS) UKA are asymmetric and narrower compared to femoral condylar widths allowing the surgeon to place the component more medial or lateral [3] to improve central tracking on the tibial component. However, a symmetric straight femoral component would fit better on the lateral condyle. The challenge of lateral UKA using off-the-shelf (OTS) UKA is to place an implant shaped more to the medial condyle on the lateral condyle.

The same challenge exist for the tibial component. The medial condyle is more D-shaped and not as round as the lateral tibial plateau (fig. 4).

Doing a lateral UKA through a mini-invasive medial approach is impossible. A mini invasive lateral approach is more difficult and requires attention to certain details. Exposure is limited due to the patellar tendon and the more lateral sitting patella. In order to subluxate the patella medially a longer arthrotomy is necessary in most cases. Surgeons place the not wide enough femoral component as lateral as possible on the femoral condyle and move the tibial component more medial to compensate for the shortcomings of implant design (not wide enough). Placement of the tibial component in 10 to 20 degrees of internal rotation is also recommended to allow centerline articulation [4] but may require to perform the vertical “L” cut through the patella tendon (fig. 5). It remains unclear whether posteromedial tibial coverage of the lateral tibia plateau is sufficient to allow for lateral rollback in deep flexion. Custom implants not only restore the geometry of the lateral tibiofemoral joint, but also simplify the surgical technique and may open this satisfying procedure to more patients with isolated lateral tibiofemoral osteoarthritis with the potential to improve mixed results reported in the literature [4-7].

Table 1: Medial and lateral femoral Ap and ML dimensions are different and there are significant differences between males and females [3]

	Total	Males	Females	p-Value Comparing Males To females
Height (cm)	168.7 (10.3)	173.6 (9.1)	163.4 (8.9)	p < 0.001
Weight (kg)	73.8 (21.9)	74.9 (22.2)	72 ?6 (20.6)	p = 0.715
Medial Tibia AP Length	5.06 (0.46)	5.37 (0.38)	4.75 (0.29)	p < 0.001
Medial Tibia ML Width	3.04 (0.32)	3.27 (0.25)	2.82 (0.19)	p < 0.001
Lateral Tibia AP Length	4.74 (0.46)	5.03 (0.34)	4.45 (0.38)	p < 0.001
Lateral Tibia MpL Width	3.21 (0.32)	3 .41 (0.26)	3.01 (0.23)	p < 0.001
Medial Condyle AP Length	5.73 (0.45)	6.01 (0.33)	5.45 (0.37)	p < 0.001
Medial Condylar ML Width	2.61 (0.29)	2.80 (0.23)	2.43 (0.22)	p < 0.001
Lateral Condyle AP Length	6.23 (0.51)	6.55 (0.35)	5.92 (0.45)	p < 0.001
Lateral Condylar ML Width	2.85 (0.33)	3.09 (0.25)	2.61 (0.19)	p < 0.001
Med/Fem Art. Surface AP Length	4.84 (0.41)	5.04 (0.35)	4.65 (0.38)	p < 0.001
Lat/Fem Art. Surface AP Length	4.46 (0.47)	4.71 (0.41)	4.22 (0.41)	p < 0.001
Lateral Tibia AP/ML Ratio	1.48 (0.09)	1.48 (0.11)	1.48 (0.08)	p = 0.869
Medial Tibia AP/ML Ratio	1.67 (0.09)	1.64 (0.10)	1.69 (0.08)	p = 0.093
Lateral Condyle AP/ML Ratio	2.20 (0.17)	2.13 (0.17)	2.27 (0.12)	p = 0.002
Medial Condyle AP/ML Ratio	2.21 (0.18)	2.16 (0.19)	2.25 (0.18)	p = 0.080

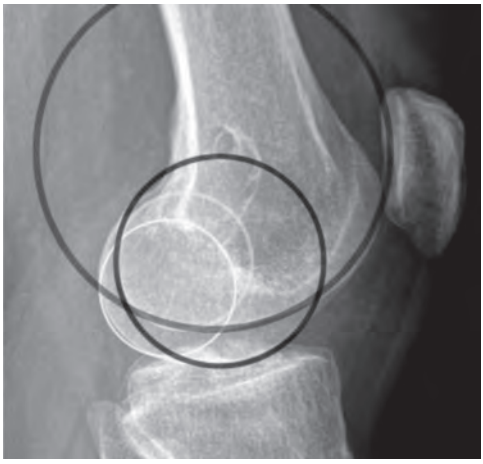

Fig. 1: Medial and lateral femoral condyles have similar posterior but different anterior radii [1]. The anterior lateral radius is twice as large compared to the anterior medial radius.

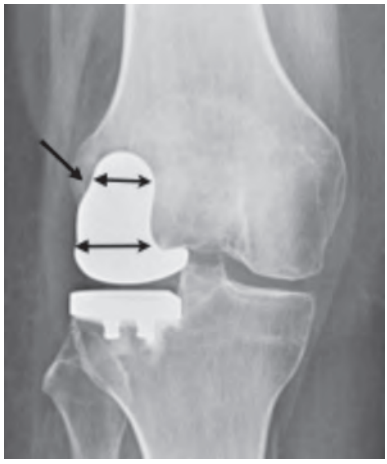

Fig. 2: Different geometry of the lateral femoral condyle showing a custom lateral UKA. The posterior condyle is much narrower compared to the width more anteriorly.

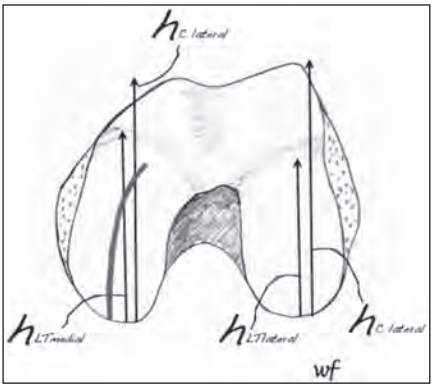

Fig. 3: Geometric differences between medial and lateral tibial plateau. Note the more curved medial condyle.

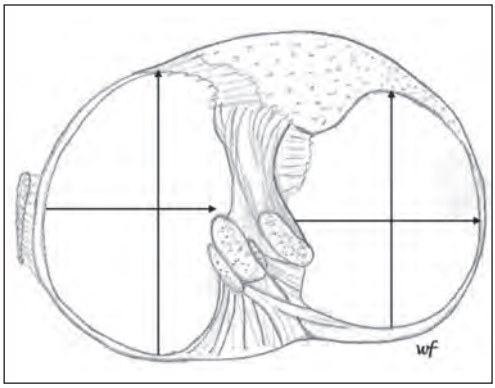

Fig. 4: Different geometries of medial and lateral tibial plateau. The medial tibial condyle is tear-drop shaped and the lateral tibial plateau more round.

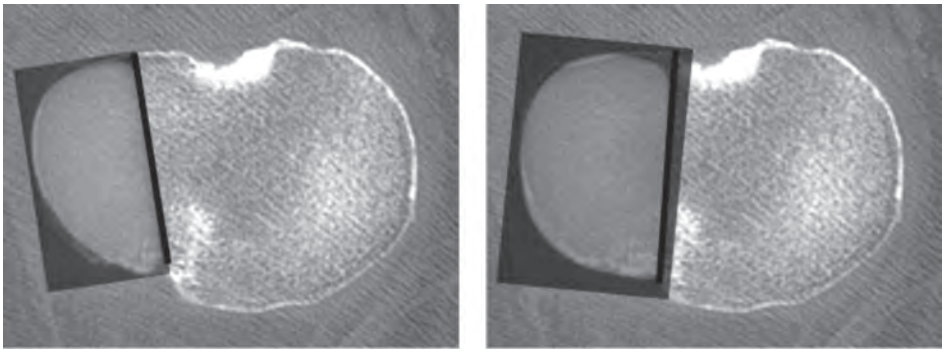

Fig. 5: It is recommended to internally rotate a OTS lateral UKA 10-20 degrees, which may require to cut through the patella tendon [8] as seen on the left. A custom lateral UKA is designed to cover the entire lateral tibial plateau and does not require to make the L-cut through the patella tendon.

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MEDIAL VERSUS LATERAL PARAPATELLAR APPROACH FOR TOTAL KNEE ARTHROPLASTY IN PATIENTS WITH MODERATE VALGUS DEFORMITY

R.A. MAGNUSSEN, S. GUNST, V. VILLA, C. DEBETTE, O. REYNAUD, E. SERVIEN, S. LUSTIG, P. NEYRET

BACKGROUND

When performing total knee arthroplasty (TKA) in the setting of osteoarthritis with valgus deformities, the surgeon can choose whether to approach the joint via a standard medial parapatellar approach, or via a lateral parapatellar approach. Keblish [4] recommended a lateral parapatellar approach for knees with a fixed valgus deformity as this method provides direct access to the lateral structures, facilitating ligament balance. But for many authors, the lateral approach is considered difficult, and is associated with greater complication rates. The purpose of this single center study was to compare surgical factors and short-term clinical and radiographic outcomes of the medial and lateral approach for TKA in knees with moderate valgus (<10°).

METHODS

Four hundred and twenty four knees undergoing TKA with a pre-operative valgus deformity between 3 and 10 degrees were identified through queries of a prospectively collected TKA database. 109 knees were treated via a medial approach and 315 knees were treated via a lateral approach. The Tornier HLS TKA system was used for all knees. Intra-operative variables that were assessed included surgical time, tourniquet time, the type of lateral releases that were performed, and whether a tibial tubercle osteotomy was required. International Knee Society (IKS) knee and functional scores and radiographic alignment were compared post-operative with a minimum of two years follow-up. Fisher's exact tests were used to compare categorical variables, and *t*-tests were used for continuous variables, with statistical significance defined as $p < 0.05$.

RESULTS

Tourniquet time (p=0.25) and surgical time (p=0.62) were not significantly different between the two groups. The popliteus tendon was released more frequently in the medial approach group (p=0.04), while the iliotibial band was released more frequently in the lateral approach group (p<0.001). A tibial tuberosity osteotomy was performed more frequently in the lateral approach group than in the medial approach group (20.8% vs 8%).

At final follow-up, no significant differences in limb alignment (p=0.78), IKS knee (p=0.32) or function (p=0.47) scores were noted based on surgical approach. The complication rates were similar in the two groups (p=0.53).

DISCUSSION AND CONCLUSION

The main finding of this study was both the medial and lateral parapatellar approaches resulted in similar, good results following TKA in knees with mild valgus.

The achievement of a balanced knee may be more difficult in cases of valgus deformity than in knees with standard varus osteoarthritis, possibly resulting in excessive releases of lateral structures. The main theoretical advantage of the lateral approach is a better visualization, and a preservation of these tight lateral tissues [7]. Previous studies have demonstrated a 20-fold increased risk of revision if both the collateral lateral ligament and the popliteus tendon are released [5]. Sekiya *et al.* found a tendency toward fewer release in their lateral approach group [8], suggesting that a capsular release is enough in most cases when performing a lateral approach.

The lateral approach also avoids patellar devascularization that can occur when a lateral retinacular release is performed in the setting of a medial parapatellar arthrotomy [3]. The increased postoperative range of motion noted by Sekiya *et al.* with the lateral approach [8] was not demonstrated in our series, possibly due to a lower preoperative valgus deformity (6°) compared to Sekiya *et al.* (13°). The lateral approach may also result in improved patellar tracking in some patients following TKA [2]. The lateral approach may be more efficient in restoring lower limb alignment as suggested by Apostolopoulos [1, 6], particularly in patients with a large valgus deviation. We did not find any difference in the post-operative mechanical axis in our series of moderate valgus, which is consistent with the results of Sekiya *et al.* [8]. For many authors, the lateral approach is not familiar technique to perform, and is considered to be technically more difficult than the medial approach. This expectation is due to the presumed necessity of performing an associated

Table 1 - Pre-operative Data

	Lateral Approach n = 315	**Medial Approach n = 109**	**Significance**
Age (years)	70.9 ± 9.4	68.1 ± 11.2	**p = 0.020**
Sex	Male = 60 (19.1%) Female = 255 (80.9%)	Male = 24 (22.0%) Female = 85 (78.0%)	p = 0.49
Weight (kg)	74.9 ± 12.7	71.2 ± 16.3	**p = 0.029**
BMI (kg/m^2)	27.6 ± 4.3	26.4 ± 5.2	**p = 0.030**
Prior open knee surgery	51 (16.2%)	15 (13.8%)	p = 0.33
OA Grade *. Grade 1* *. Grade 2* *. Grade 3* *. Grade 4*	 5 (2.0%) 68 (27.2%) 122 (49.2%) 53 (21.4%)	 2 (3.4%) 21 (35.6%) 24 (40.7%) 12 (20.3%)	p = 0.45
IKS Knee Score	51.8 ± 15.6	47.1 ± 18.2	**p = 0.017**
IKC Function Score	57.4 ± 18.7	52.1 ± 20.7	**p = 0.019**
Flexion contracture of 5 deg or greater	100 (31.7%)	39 (35.8%)	p = 0.48
Alignment *. HKAA (degrees)* *. FMA (degrees)* *. TMA (degrees)*	 186.6 ± 2.3 93.7 ± 3.0 90.4 ± 2.8	 185.4 ± 2.3 93.1 ± 3.4 89.4 ± 3.4	 **p < 0.0001** p = 0.10 **p = 0.0064**
Blakburne-Peel Index	0.84 ± 0.23	0.77 ± 0.17	**p = 0.001**

tibial tubercle osteotomy, anticipated difficulty in lateral soft tissue closure, and increased surgical time. We noted a greater number of TTO in the lateral approach group, but these were performed more often in the beginning of our study. As time passed, the TTO rate decreased, and was never performed in the last 5 years of our experience (164 patients). We did not find any difference of surgical and tourniquet time between medial and lateral approach. These results confirm that the systematic use of the lateral approach for valgus knee is safe and efficient. Further, no difference in complication risk was noted between the two groups, in spite of the more frequent performance of a TTO in the lateral approach group.

Medial and lateral parapatellar approaches resulted in similar, good results following TKA in knees with mild valgus. The lateral parapatellar approach is a safe, effective surgical technique for the performance of TKA in the setting of moderate knee valgus. Surgical time, complications, and short-term results are equivalent to the medial parapatellar approach.

Table 2 - Intra-operative

	Lateral Approach n = 315	**Medial Approach n = 109**	**Significance**
Surgical Time (minutes)	90.5 ± 23.8	89.3 ± 21.1	p = 0.62
Tourniquet Time (minutes)	78.4 ± 20.4	76.1 ± 17.1	p = 0.25
Lateral Release needed :			
. None or Capsule only	204 (64.6%)	86 (79.6%)	**p = 0.006**
. Popliteus	12 (3.8%)	13 (12.0%)	**p = 0.004**
. IT Band	86 (27.3%)	3 (2.8%)	**p < 0.0001**
. Osteotomy of LFC	1 (0.3%)	1 (0.9%)	p = 1.0
. Other	12 (4.1%)	6 (5.5%)	p = 0.42
Tibial tuberosity osteotomy	65 (28%)	9 (8%)	**p = 0.003**

Table 3 - Results

	Lateral Approach n = 238	**Medial Approach n = 89**	**Significance**
Follow-up (years)	2.8 ± 3.4	5.1 ± 4.2	**p < 0.0001**
IKS Knee Score	88.8 ± 13.7	86.9 ± 15.7	p = 0.32
IKS Function Score	74.3 ± 24.6	72.1 ± 24.8	p = 0.47
Flexion contracture of 5 deg or greater	9 (3.8%)	8 (9.0%)	p = 0.09
Alignment :			
. HKAA (degrees)	180.7 ± 2.9	180.8 ± 2.8	p = 0.78
. FMA (degrees)	90.3 ± 1.8	90.5 ± 2.0	p = 0.41
. TMA (degrees)	90.4 ± 1.9	90.1 ± 1.2	p = 0.09
Blackburne-Peel Index	0.64 ± 0.22	0.62 ± 0.21	p = 0.45
Complications :			p = 0.53
. Fracture	5 (1.5%)	3 (2.8%)	
. Skin necrosis	2 (0.6%)	1 (0.9%)	
. Infection	3 (0.9%)	3 (2.8%)	

Table 4 : Number of TTO in the lateral approach group per year

Year	Number of cases	Number of TTO
1993	2	0
1995	4	0
1996	1	0
1997	4	0
1998	5	1 (20%)
1999	11	7 (63%)
2000	16	13 (81%)
2001	13	10 (76%)
2002	14	11 (78%)
2003	9	5 (55%)
2004	20	7 (35%)
2005	25	7 (28%)
2006	27	5 (18%)
2007	33	0
2008	32	0
2009	22	0
2010	36	0
2011	41	0
Total	315	65 (20.8%)

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TECHNICAL ASPECTS OF TKA IN THE VALGUS KNEE. Modified Surgical Technique to balance the valgus knee and avoid instability

D. BEVERLAND, E. DORAN, S. O'BRIEN, J. HILL, R. PAGOTI

We have used the technique described below for over 11 years in over 540 valgus knees with a pre-operative deformity of ≥10 degrees. This is a consecutive series in which a mobile bearing LCS rotating platform was used in every case irrespective of the degree of deformity.

A midline incision with a medial approach (Insall type [1]) was used in all cases. Exposure of the proximal tibia is minimal – <10mm below medial joint line, and as far posterior as the mid-coronal plane. A "notch plasty" (clearance of osteophytes) is performed and both cruciates are excised. The tibial cut is made perpendicular to the tibial mechanical axis matching the posterior slope of medial tibial condyle. The antero-posterior (AP) femoral cuts are made using the femoral guide positioner which sets femoral rotation off the tibial axis.

After measuring the flexion gap a 5° conservative distal femoral "pre-cut" is made and the conservative extension gap is assessed with the spacer block. If the gap is unbalanced (trapezoidal gap) we use the algorithm in figure 1 to balance the knee. If it is tight laterally, and the difference between medial and lateral gap is ≥2 and ≤5mm, the gap is balanced by making a definitive cut in 60 or more degrees. This does not elevate the joint line but resects more bone from the tighter lateral side. If the difference is >5mm then this is too much to be corrected by a definitive re-cut in greater valgus and therefore a postero-lateral capsulotomy is required. The postero-lateral capsulotomy is done with the knee in full extension. The lateral joint space is opened with laminar spreaders and the popliteus tendon is identified (fig. 2). In our experience the popliteus is never tight and is never intentionally cut but its lateral border locates the tight postero-lateral capsule. This tight band which is about 10mm in width is then divided using a small blade at which point the lateral side of the joint will usually visibly open. This corrects both the fixed flexion and valgus deformity (fig. 2). Having cut the posterior capsule the extension gap is tested once more. If the difference between the medial and lateral gap is now ≤2-5mm, the gap can be balanced by making a definitive cut in 60 or more degrees (fig. 1). In type II valgus knees caution is required as the MCL has become stretched. The knee should not be fully balanced in extension, but with the spacer block in place the extension gap should stay closed medially unless a valgus stress is applied.

We never resurface the patella but if necessary a lateral patellar release is performed to allow central tracking of the patella in the trochlear

groove. In knees with a Sperner Grade 4 deformity of the patella [2] "patella contouring" (removal of the abnormal traction osteophyte) is performed (fig. 3). Postoperatively the knee is immobilised at 90 degrees flexion for six hours. We believe this reduces the risk of peroneal nerve injury and we have also shown that it reduces blood loss [3].

All components were cementless, except in 14 patients (2.6%) where bone was considered poor and cement was used on the tibial side [4]. However in the last five years no cemented component has been used. When using a cementless tibial tray care should be taken to use autologous bone graft in any areas of soft and then ensure that during impaction the tibial tray descends evenly from medial to lateral and anterior to posterior.

When using this technique with a pre-operative valgus deformity of ≥10 degrees approximately 70% of patients have a release of the postero-lateral capsule either with or without a definitive cut of ≥6 degrees, a further 20% just have a definitive cut of ≥6 degrees and 10% have a definitive cut of 5 degrees. The IT band was released in 16 patients (3%) but this was only in the earlier part of this series. We no longer release the IT band.

Lateral patellar release was performed in 75 knees (14%) and 45 knees (8.3%) had patellar contouring. The incidence of lateral patellar release in knees ≥200 deformity was twice that of knees with 10-190 deformity. (24.5% vs. 11.7%) (Fisher's exact test the *p*-value is 0.026). This compares to a 4% lateral patellar release in our varus knees.

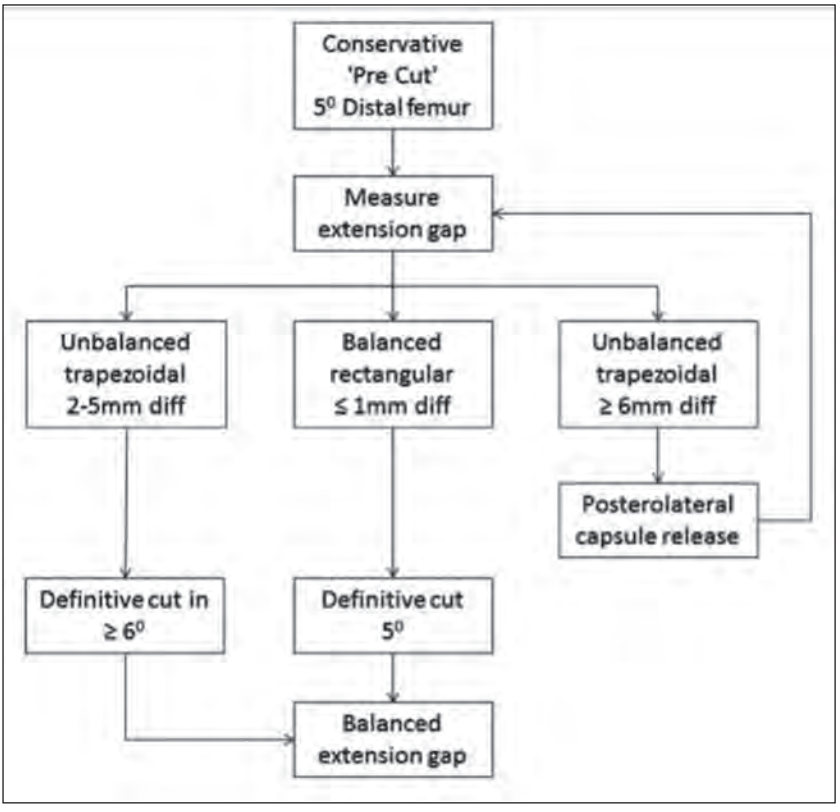

Fig. 1: Algorithm to balance the extension gap in valgus knees.

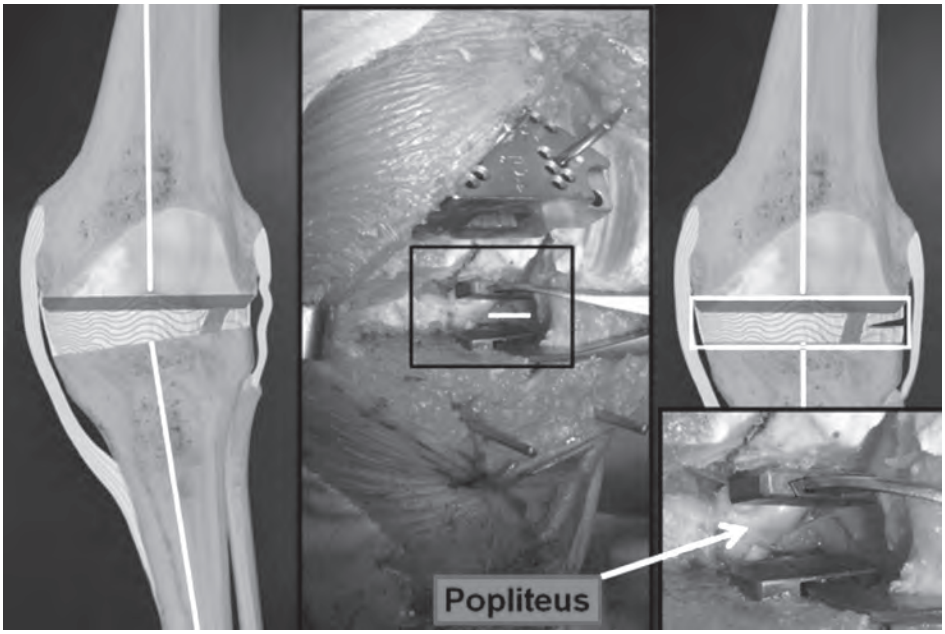

Fig. 2: Balance of extension gap with postero-lateral capsule release.

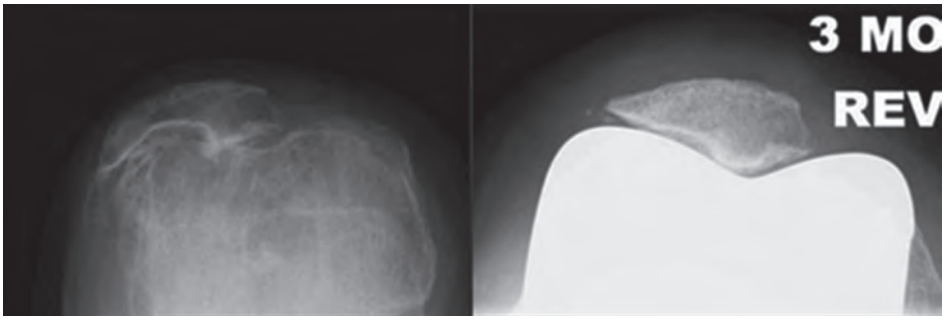

Fig. 3: Example of patella contouring.

RESULTS AND COMPLICATIONS

We have used this technique for over 11 years in over 540 patients with pre-operative valgus knee deformity ≥10 degrees. Average age was 72 (48-87 years) with 448 female (83%) and 92 male (17%) patients. Mean Body Mass Index (BMI) was 29.2 kg/m2 (18.5-43.9). Primary diagnosis was osteoarthritis in 491knees (91%), rheumatoid arthritis in 39 knees (7.2%) and inflammatory or psoriatic arthritis in 10 knees (1.8%).

Of those 540 patients 270 are between 6 and 11 years from surgery. In this latter group with a longer follow-up we report good to excellent outcomes at one year in 93% of knees. The mean postoperative AKS clinical score was 86.5 (±12.5) and functional score was 67.9 (±19.7).

Revisions

With respect to the group of 270 patients who are between 6 and 11 years from surgery there have been 3 revisions.

- **One patient** with subsidence of a cementless tibial tray at three months was revised to a cemented long-stemmed component. Post-operatively the patient's AKS clinical score improved to 71, ROM is 0-1050 and 7 years since surgery she remains pain free.
- **Two patients** had open washout within 3 weeks of the index operation with change of the polyethylene insert. Both patients have since died of unrelated causes free of infection at 4 and 7 years.

A further 5 knees had additional surgery for problems relating to their knee :

- One patient had an arthroscopic washout for infection 32 months after index operation and remains infection free, 6 years since the washout;
- One patient had a washout of the knee for haematoma one week after surgery, with no further problems;
- Two patients had manipulation under anesthesia (MUA). The first patient had a ROM of 10-750 preoperatively, 0-320 6 months post-operatively and, following MUA, 0-450 one year post-operatively. The second patient had a ROM of 5-1200 pre-operatively, 5-600 three months post-operatively and following MUA, 0-1050 one year post-operatively;
- There was one non-recurrent "spin out" [5] of the mobile bearing at 4 weeks managed by closed reduction and plaster cast in extension for eight weeks.

Other non-operative complications

One patient required a vacuum pump for wound dehiscence but at most recent review (77 months) reported no problems.

There were two patients who had severe pre-operative Patello-Femoral osteoarthritis with postoperative patellar instability. One patient responded to six weeks of immobilisation in an extension knee brace. One year post-operatively she had a ROM of 0-1000 without further patellar subluxation. The second patient had a recurrence of a chronic pre-operative patella dislocation at three months. Despite eight weeks of plaster cast treatment she did not improve and remains dislocated. She has refused any further treatment and is able to mobilise with an extension brace. We have had no cases common peroneal nerve palsy following a valgus knee.

DISCUSSION

Patellar dislocation as a problem after TKA for valgus deformity has been reported in up to 2% to 4% [6]. In the present series there were two patients with post-operative patellar problems (0.4%). Higher rates of lateral release have been reported for valgus knees to prevent patellar maltracking. Stern *et al.* [7] and Aglietti *et al.* [l8] reported a 76 and 67% rate of lateral patellar release for valgus knees respectively. In the present study only 14% required lateral patellar release, and 93.1% achieved central patello-femoral alignment.

Common peroneal nerve palsy has been reported in up to 4% [7] of valgus knees. There were no cases in our series. We feel that a combination of minimal soft tissue release, avoidance of over correction and immobilising the knee in flexion post-operatively decreases the tension in the nerve.

In the past several studies have shown that alignment effects the survival of total knee arthroplasty [9, 10]. However, Smith *et al.* [11] found that alignment did not affect the incidence or progression of radiolucent lines or clinical outcome post-operatively. More recent studies by Parratte *et al.* [12] suggest that achieving a neutral mechanical axis may not always be the right target in TKA as it may not correlate with long term survival. Other published work however supports the opposite view (Mullaji A *et al.* [13]. Our Philosophy is to achieve a balanced extension gap rather than the more traditional focus on a neutral mechanical axis. We accepted 70 of MAD as an acceptable

alignment. This may seem excessive to many surgeons but the patients have not complained about the residual deformity presumably because of their premorbid valgus alignment.

CONCLUSION

We have described a modified technique for the correction of the valgus arthritic knee. It consists of dividing the postero-lateral capsule when the deformity is fixed, with an adjustment to the angle of the distal femoral cut to balance the extension gap. We have achieved adequate correction of deformity with a low complication rate and satisfactory outcome in the medium term. In our opinion extensive release of soft tissues in valgus knees is not required, and therefore avoids the associated higher rate of complications and increased morbidity.

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CARTILAGE, TIBIAL SLOPE AND HTO

S. LUSTIG, C. SCHOLES, M. COOLICAN, D. PARKER

INTRODUCTION

In contrast to radiographic measurements, MRI provides multiple slices of the knee joint in the sagittal plane, making it possible to assess the medial and lateral tibial slope separately. The purpose of this study is to investigate the effect of medial open-wedge high tibial osteotomy (MOWHTO) on bony and meniscal slope in the medial and lateral tibiofemoral compartments. It was hypothesised that greater changes on the medial tibial plateau would be observed compared with the lateral one.

METHODS (fig. 1, 2 and 3)

A retrospective analysis of prospectively collected data was performed on pre- and post-operative MRIs from 21 patients (17 men and 4 women; age 52±9 years). Inclusion criteria were varus alignment, medial compartment osteoarthritis and election for a primary MOWHTO. Each patient had a preoperative and a post-operative highresolution MRI (3Tesla, Magnetom Trio, Siemens AG) at an average follow-up of 2.1 years. A previously published method was used to measure bony and meniscal slope for each compartment. The difference between pre- and postoperative tibial slope for both compartments was calculated and associated with the amount of frontal correction.

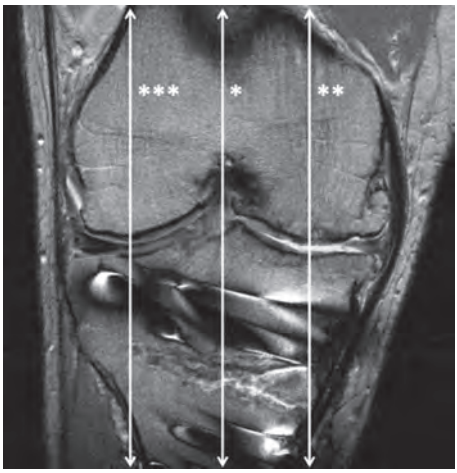

Fig. 1: Post-operative MRI, 2 years after an opening-wedge high tibial osteotomy. Sagittal images were identified from the axial images at the joint line for the mid-sagittal slice (single asterisk), the mid-medial tibial plateau (double asterisks) and the mid-lateral tibial plateau (triple asterisks).

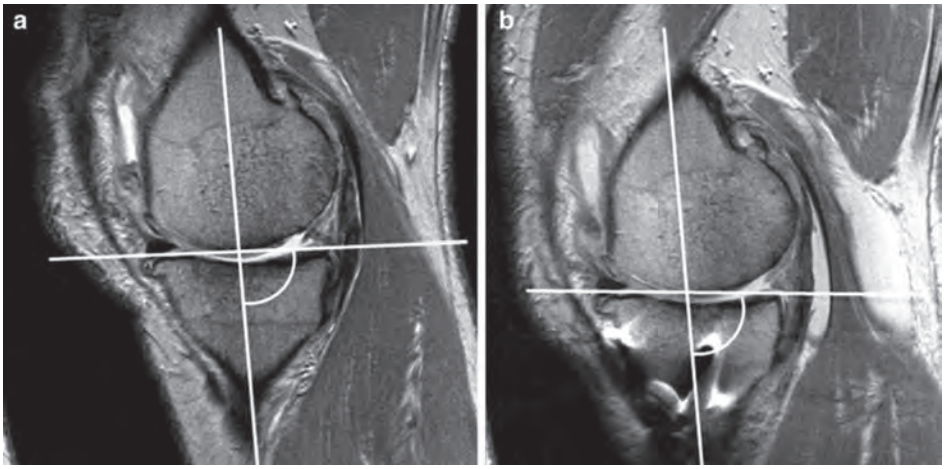

Fig. 2: Sagittal plane section in the middle of the medial tibial plateau was used for measurement of tibial slope preoperatively (a) and postoperatively (b). The most superior points in the anterior and posterior part of the medial tibial plateau were joined to obtain the line of the bony slope. It was not possible to identify the limits of the medial meniscus due to osteoarthritic changes.

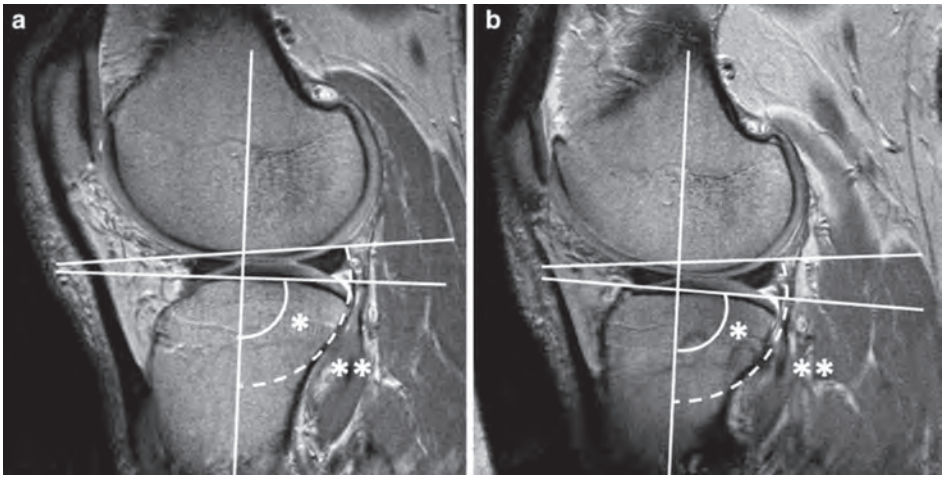

Fig. 3: Mid-sagittal images used for measurement of lateral tibial slope preoperatively (a) and post-operatively (b). The most superior points in the anterior and posterior part of the lateral tibial plateau were joined to obtain the line of the bony slope in the lateral compartment (single asterisk). Similarly, the highest points of the interior and posterior horn of the lateral menisci were joined to generate the line of soft tissue slope in the lateral compartment (double asterisks).

RESULTS (Table 1)

There was a significant increase in bony tibial slope in both compartments following MOWHTO. When a change in bony tibial slope was detected in an individual patient, the change was larger in the medial compartment, with the average change also significantly greater ($p<0.01$) in the medial compartment (2.4°±1.3°) compared with the lateral compartment (0.9°±1.1°). There was also a significant increase ($p<0.01$) in the lateral tibial meniscal slope of 0.9°±1.4°, which was equivalent to the change in the bony lateral slope. The amount of frontal correction was not significantly associated with the amount of change in slope.

CONCLUSIONS

The results suggest that the modification of the bony slope is larger in the medial compartment after MOWHTO, which is likely related to the location of the hinge on the lateral tibial cortex. These findings suggest that consideration of the medial and lateral tibial slope intra-operatively could be important to identify the optimal location of the hinge. However, further studies are required before recommending any modification to the surgical technique, as the potential clinical consequences of tibial slope alterations remain unknown.

Table 1 : Preoperative and post-operative measurements (°) of bony and meniscal slopes in the medial and lateral compartments of the knee.

	Preoperative	Post-operative	Changes	p Value
Medial Bony Slope	93.6 ± 4.3	96.0 ± 4.0	2.4 ± 1.3	p<0.01
Lateral Bony Slope	95.5 ± 3.4	96.4 ± 3.3	0.9 ± 1.1	p<0.01
Medial Meniscal Slope	NA	NA	NA	P<0.01
Lateral Meniscal Slope	91.2 ± 3.1	92.1 ± 3.3	0.9 ± 1.4	p = 0.01

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TIBIAL SLOPE AND OSTEOTOMY: TECHNICAL ASPECTS

S. TOMES, G. DESCHAMPS

INTRODUCTION

High tibial osteotomy (HTO) is a surgical technique that gives good results in the management of degenerative osteoarthritis of the knee with frontal distortion in genu varum [1, 2].

Two main surgical procedures predominate: opening wedge (OWHTO) and closed wedge high tibial osteotomy (CWHTO).

According to the literature, the first has one well-known side effect: The increase in the tibial slope [3-6], which is responsible for increased strain in the anterior cruciate ligament [7].

Nevertheless, we put forward the hypothesis that the tibial slope can be modified by the positioning of the wedge and especially that posterior positioning can limit this side effect.

MATERIALS AND METHODS

This study involved 141 patients operated on by a single surgeon (GD) between March 2007 and November 2009. For each patient, opening-wedge high tibial osteotomy (OWHTO) was performed for medial degenerative osteoarthritis of the knee. No exclusion criteria were used.

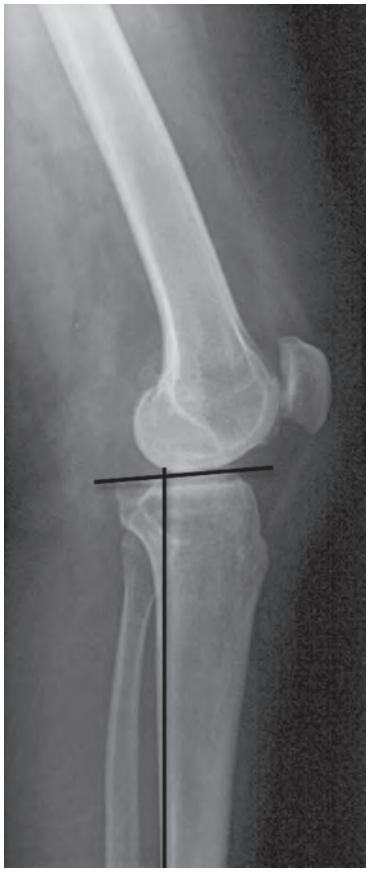

Fig. 1: Posterior tibial slope measurement (Brazier et al.)

X-rays were done for each patient (full-length anterior-posterior weight-bearing view, a.p. knee X-ray and knee in profile) three times: At the pre-operative time, at the fifth day after surgery and at the last follow-up.

The tibial slope was measured on the knee in profile X-rays with the cortical posterior reference described by Brazier *et al.* [8].

Each patient was assessed with the Knee Society Score (KSS) [9], pre-operatively and at the last follow-up.

SURGICAL TECHNIQUE FOR OPENING WEDGE HIGH TIBIAL OSTEOTOMY

The patient is in the supine position, with knee flexion around 90 degrees and a tourniquet.

The approach is medial through an eight-centimeter incision.

The medial collateral ligament (superficials fibers) is cut perpendicularly to the major axis. Beforehand, we have detached the pes anserinus from its insertion and retracted it, the cut forming a reversed L. The pes anserinus is used to cover the plate at the end of the surgery. A scaler is used to free the soft tissue at the posterior part of the tibia. Posterior blood vessels and the patellar tendon are protected by two retractors. Then an oblique osteotomy is performed with an oscillating saw, completed with a chisel (to cut through the posterior cortex of the bone completely). The osteotomy is then opened and a trial wedge is positioned. Then, the final wedge (we use a bone bank wedge) is put in place. To position the wedge as posteriorly as possible, the posterior part of the wedge is positioned parallel to the posterior part of the cortical bone.

It is important to remember two essential elements: First, it is necessary to cut the posterior part of the cortical bone completely and second, it is important to position the final wedge parallel to the posterior tibial cortex.

The final part of this surgery is the fixation of the osteotomy with a plate. We used the Activmotion plate (NEWCLIP®).

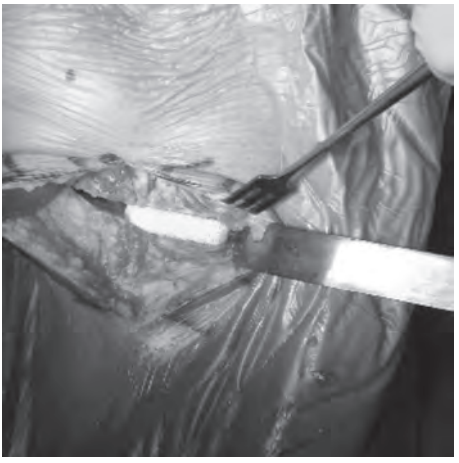

Fig. 2: Profile view of osteotomy (The retractor is posterior). The final wedge is posterior and the posterior gap is larger than the anterior.

STATISTICAL ANALYSIS

The various values of tibial slope and KSS score were compared using the bilateral paired parametric Student test ($p<0.05$) when the distribution was normal.

RESULTS

In this study, the mean follow-up was 42.7 months (26-65), the mean age was 56.6 years (28-73), the sex-ratio was 3.8 M/1 F, and the mean BMI was 26.5 kg/m^2 (18.9-40.4).

The mean pre-operative medial tibial slope was 5.4° (-2-13), 5.8° (-2-12) at the 5th day and 5.8° (-2-12) at the last follow-up. There was no statistically significant difference ($p=0.8$).

Concerning the clinical assessment, The International Knee Society Score results varied from 127.7 to 186.1 and the difference was statically significant ($p<0.001$).

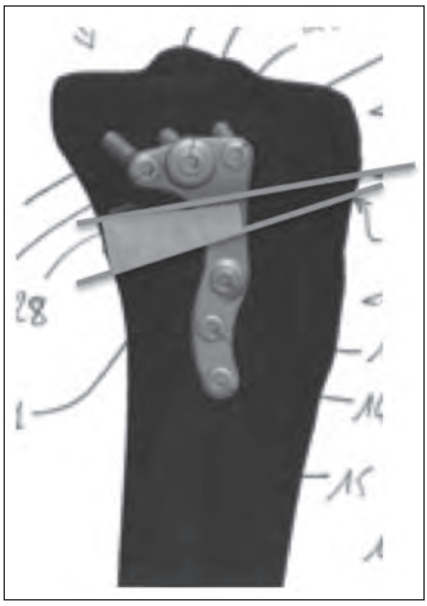

Fig. 3 : Example of posterior positioning of the wedge.

DISCUSSION

Nowadays, 2 main surgical techniques, cwhto and owhto, are available and each has its particular side effect. The choice of one or the other depends on many criteria, and often on the surgeon's usual practices.

No study has assessed wedge positioning and its impact on the tibial slope, except for Marti, who put the wedge more posterior when he associated osteotomy with anterior cruciate ligament repair [10].

Moreover, it is difficult to compare results of several studies, given the different methods to measure tibial slope, especially when there is no correlation between them.

Our study showed an increase in tibial slope of about 0.4°. When we compared our results with those in the literature, we found, on average, an increase of about 3° [3-6, 10]. But in all of the other studies, the positioning of the wedge was never mentioned.

Joon [11] showed a difference in tibial slope, depending on whether or not he cut through the posterior cortex of the bone completely. For us, the cortex must be cut through completely so as to position the wedge as posteriorly as possible.

Noyes [12] showed that to have no modification of the tibial slope after opening-wedge high tibial osteotomy, a difference between anterior and posterior gap is needed, with the posterior gap twice as wide as the anterior gap, and for each increase of one millimeter in the anterior gap, 2 degrees of tibial slope is gained.

Posterior positioning of the wedge automatically leads to a wider posterior gap.

Unfortunately, no study has yet compared anterior positioning with posterior positioning of the wedge and its impact on the tibial slope. This issue has to be studied.

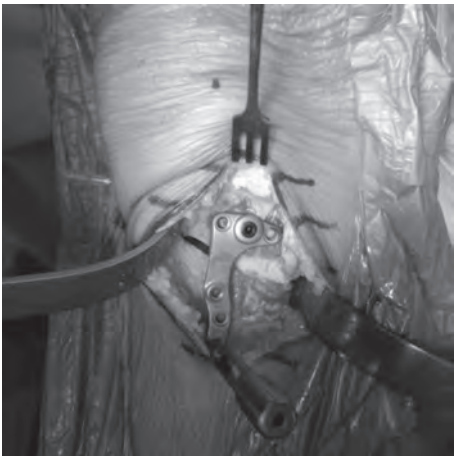

Fig. 4: Profile view of the posterior positioning of the wedge.

CONCLUSION

The cause of the increase in tibial slope after OWHTO has not been totally elucidated, but our study shows an encouraging way to go.

Our surgical technique allows us to expand the indication for OWHTO, particularly in two cases: First of all, in anterior chronic laxity, with no risk of exacerbating knee pain after surgery (without increasing tibial translation).

Then, secondly, it is possible to perform OWHTO and anterior cruciate ligament repair at the same time, without increasing strain on the transplant.

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DOUBLE LEVEL OSTEOTOMY FOR GENU VARUM DEFORMITY

D. SARAGAGLIA, M. BLAYSAT, M. GRIMALDI

INTRODUCTION

Medial knee osteoarthritis is not uncommon and high tibial osteotomy (HTO) was described for the first time more than 50 years ago [7, 9, 13]. Nowadays, HTO remains a good option [3, 4, 5, 8, 11, 17, 24, 27], despite the large expansion of total knee replacement (TKR) or the revival of unicompartmental knee prosthesis boosted by the less-invasive surgery concept. It is well indicated for "young" and active people (less than 65 years of age) with moderate arthrosis (narrowing joint line up to 100% without any bone wear or instability). Nevertheless it is a demanding surgery, which exposes to excessive over or under correction likely to lead quickly to failure [8, 24, 26] or oblique joint line leading to more difficulties in performing TKR (fig. 1). This oblique joint line corresponds to an excessive valgus of the tibial mechanical axis [1]. It is all the more frequent when varus is important whether for a femoral or a femoral and tibial deformity. The desirable overcorrection to achieve a good clinical result (3 to 6°) increases even more this oblique joint line. When it reaches 10° of valgus one must often perform an osteotomy to set the tibial mechanical axis back to 90° [14] before implanting the prosthesis.

We thought for a long time that combined femoral and tibial osteotomy was a suitable procedure to avoid this drawback, but, because of the difficulty to obtain an accurate lower leg axis without any reproducible assistance, we had performed it in only a few cases.

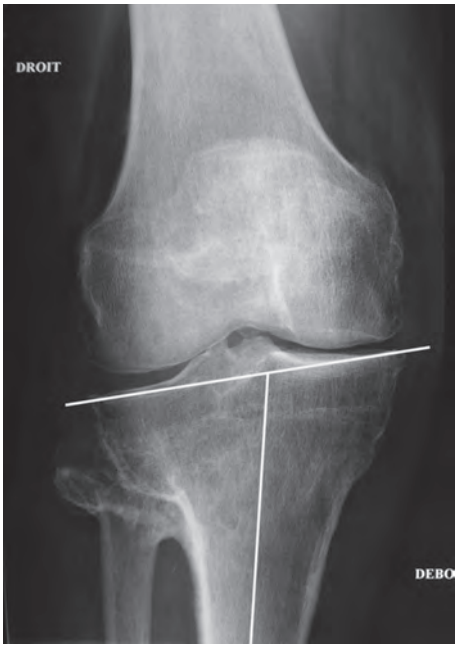

Fig. 1: Severe oblique joint line after high tibial osteotomy. Notice the extreme tibial valgus.

Drawing on our experience with TKR and HTO navigation [15, 19, 20] we used the principles of computer-assisted surgery for double level osteotomy (DLO) hoping to increase the accuracy of this difficult procedure. Our experience is based on 72 DLO performed between August 2001 and June 2014, out of 600 personal computer-assisted knee osteotomies for genu varum deformities (12%).

The objective of this article is to present the clinical and radiological results of the first 42 patients at a mean follow-up of 46 ± 27 months.

MATERIAL AND METHODS

The series was composed of 38 patients (4 bilateral), 9 females and 29 males aged from 39 to 64 years (mean age: 50.9 ± 7.1 years). We operated on 22 right knees and 20 left ones. The mean BMI was 29.3 ± 4.3 for a mean height of 171cm and a mean weight of 85.8kg. For functional assessment, we used the Lysholm-Tegner score [25] to evaluate patients, both pre-operatively as post-operatively. We felt this scoring system was better adapted than the IKS score usually used to evaluate surgical treatment for knee osteoarthritis. The mean score was of 41.2 ± 8.9 points (22-69). According to modified Ahlbäck criteria [21], we operated on 9 stage 2, 25 stage 3, 7 stage 4 and 1 stage 5. We measured HKA (Hip-Knee-Ankle) angle using Ramadier's protocol [16] and we also measured the medial distal femoral mechanical axis (MDFMA) and the medial proximal tibial mechanical axis (MPTMA) to pose the right indication [23]. These measures were respectively: 167.7° ± 3.5° (159°-172°), 87.28° ± 1.41° (83°-90°) for the MDFMA and 83.51° ± 2.7° (78°-88°) for the MPTMA.

The inclusion criteria were a patient younger than 65 years old with a severe varus deformity (more than 8° - HKA angle ≤ to 172°) and a MDFMA at 91° or less (fig. 2).

All the osteotomies were navigated using the Orthopilot® device *(B-Braun-Aesculap, Tuttlingen, Germany)*. The procedure was performed as described previously [23]: after inserting the rigid-bodies and calibrating the lower leg, we did first the femoral closing wedge osteotomy (from 4 to 7mm) which was fixed by an AO T-Plate, and secondly, after checking the residual varus, the tibial opening wedge osteotomy using a Biosorb® wedge (β Tricalcium phosphate, SBM, Lourdes, France) and a plate (AO T-plate or C-plate). The goals of the osteotomy were to achieve an HKA angle of 182° ± 2° and a MPTMA angle of 90° ± 2°.

The functional results were evaluated not only according to the Lyshölm-Tegner score [25] but also to the KOOS score [18]. The patients answered the questionnaire at revision or by

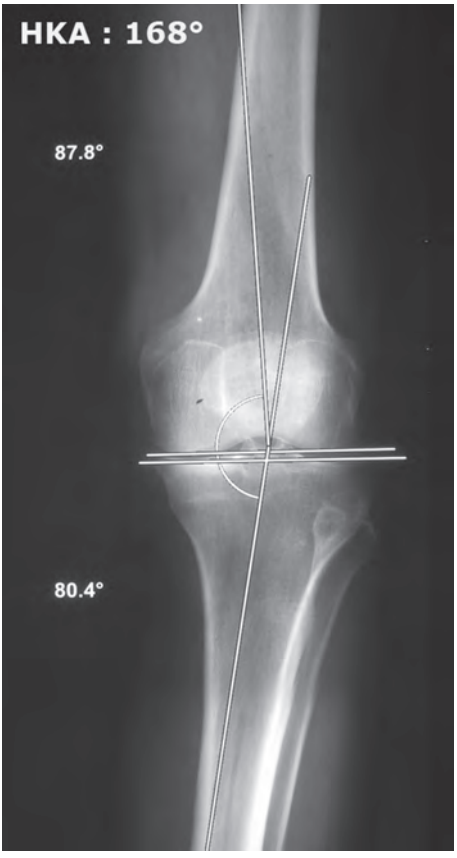

Fig. 2: Severe genu varum deformity with MDFMA at 87.8°, MPTMA at 80.4° and HKA angle at 168°.

phone, and the radiological results were assessed by plain radiographs and standing long leg X-Rays between 3 and 6 months postoperatively.

RESULTS

We had no complication in this series but one case of recurrence of the deformity related to an impaction of the femoral osteotomy on the medial side (heavy patient). 2 patients were lost to follow-up after removing of the plates (24 months) but were included in the results because the file was complete at that date. All the patients were assessed at a mean follow-up of 46 ± 27 months (12-108).

The mean Lyshölm-Tegner score was 83.3 ± 7.5 points (62-91) and the mean KOOS score was 95.1 ± 3.2 points (89-100). 40 patients were satisfied [22] or very satisfied [18] of the result. Only 2 were poorly satisfied.

Regarding the radiological results, if we exclude the patient who had a loss of correction not related to navigation, the goals were reached in 39 cases (92.7%) for the HKA angle and in 36 cases (88.1%) for the MPTMA with only one case at 93°. The mean angles were: 181.83° ± 1.80° (177°-185°) for HKA, 89.71° ± 1.72° (85°-93°) for MPTMA and 92.76° ± 2.02° (89°-97°) for MDFMA.

At that mid-term follow-up no patient had revision to a total knee arthroplasty.

DISCUSSION

Combined distal femoral and proximal tibial osteotomy in the treatment of genu varum is technically difficult. Little has been said about this technique in the literature and we could find only one paper reporting on it [1]. It seems that this technique was first described by Benjamin [2] in 1969 for the treatment of rheumatoid arthritis of the knee, but at the time, he did not mention any HKA angle or joint line obliquity. In their paper Babis *et al.* [1] reported on 24 patients (29 knees) operated on with a conventional technique (two closing wedge osteotomies). The mean preoperative HKA angle was 193.3° (that is 13.3° of varus) and they used a computer-aided analysis of the mechanical status of the knee for preoperative planning. This was limited to preoperative evaluation, and the reliability of the preoperative radiographic evaluation was not assessed. The results showed a mean postoperative HKA angle of 176.9° (169.4° to 184.9°). They had a residual varus in 2 cases (4.6° and 4.9°) and an over correction of more than 4° in 10 cases and more than 6° in 5. One knows that an under correction may lead to failure of the operative procedure and a too much overcorrection to cosmetic discomfort.

The difficulty of the technique comes from the fact that once the first osteotomy is performed, wether femoral or tibial, landmarks change and the ability to achieve a satisfactory alignment with the second osteotomy becomes challenging in the absence of reliable intra-operative landmarks. Martres *et al.* [12] suggested performing this operation in two different stages to improve its accuracy and reproducibility. It is also justified to consider that complication occuring at both osteotomy sites could lead to disastrous result. In our series we had no non-union and only one mal-union related to a secondary medial impaction of the femoral osteotomy in an heavy patient. Currently, we use a locking plate in spite of an AO T-plate, which could avoid this complication. On the other hand, every surgeon operating osteoarthritic knees should be aware of the risk of mal-union in the proximal tibia, for a procedure that is often considered temporary. In fact every osteotomy in a young adult is susceptible to lead subsequently to a TKR, and thus it is essential to plan ahead for the iterative surgery called revision.

Computer-assistance allows controlling the femoro-tibial axis (HKA angle) at every step of the procedure and thus makes it more accurate. Our current results are not far from a previous preliminary series [22] and argue in favor of a high reproducibility of this procedure. On a clinical point of view the mean Lyshölm-Tegner score improved from 41.2 ± 8.9 points

to 83.3 ± 7.5 points and the mean KOOS score was of 95.1 ± 3.2 points. These Clinical results are remarkable and the satisfaction of the patients is very high (95% of the patients satisfied or very satisfied). At mid-term follow up no patient was revised to TKR or to another osteotomy. This issue could be related not only to the accurate correction – good over correction and no oblique joint line – but also to the vascular effect of double osteotomy at each side of the joint line.

When should double level osteotomy be performed? If we consider the "normal" mechanical axis of the lower limb as described by Kapandji [10] and later taken up by Hungerford and Krackow [6] it should be 180° with an MDFMA of 93° and an MPTMA of 87° resulting in a joint line perfectly parallel to the ground. However this assumption is not confirmed in case of osteoarthritis with varus misalignement, because, in a personal unpublished series of 89 TKR, we found an MDFMA of 93° in only 43.8% of cases; It was at 90° in 33.7% of the cases, below 90° in 13.5% and above 93° in 9%.

Thus, before performing high tibial osteotomy, it is crucial to have high quality and reproducible full-length AP radiographs of the lower limb, according to a specific protocol [23]. The HKA angle, the MDFMA and the MPTMA should be determined on this goniometry (fig. 2). Lateral instability testing has become less important than it once was, since the indications for osteotomy in this setting have become rare. In case of femoral valgus (MDFMA > 90°-91°), it is illogical to perform a femoral osteotomy because we do not want to create in the femur, the error, we are trying to avoid in the tibia. If the femur is in varus or at 90°, we think that, we should proceed with a femoral osteotomy to achieve an MDFMA of around 93° (93° ± 2°), and then complete it with a tibial osteotomy to achieve an HKA angle of 182° ± 2°. In our experience, it is useless to overcorrect more than this, to obtain satisfactory results (fig. 3, 4). Overcorrection, whether femoral or tibial, can distort the anatomy and lead to a much more complicated revision TKR. Our mid-term results have trend to confirm this assertion. However, we think that a longer follow-up is needed to prove that overcorrection by ± 2° is enough for a lasting good result. If the tibia is not in varus (MPTMA over 88°), we should perform a femoral osteotomy especially if the femur is at 90° or in varus or contraindicate any osteotomy if it leads to joint line obliquity of more than 5°. If we stick strictly to these criteria, indications for double level osteotomy will likely increase with the development of navigation systems, especially since, as we said before, femurs in varus are not rare, and more so, those at 90°.

Finally, despite our trust in opening wedge osteotomies [24], we think that, at the femoral level, one should perform a closing wedge osteotomy to avoid excessive lengthening of the limb (double opening).

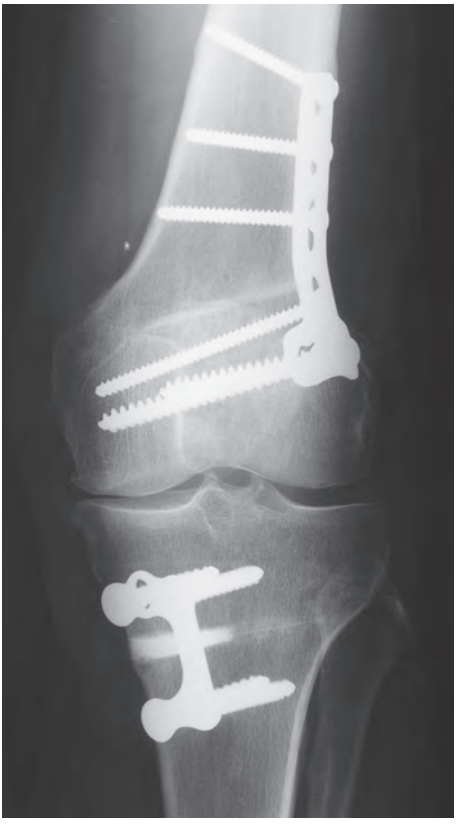

Fig. 3: DLO of the case of figure 2: notice that the joint line is horizontal.

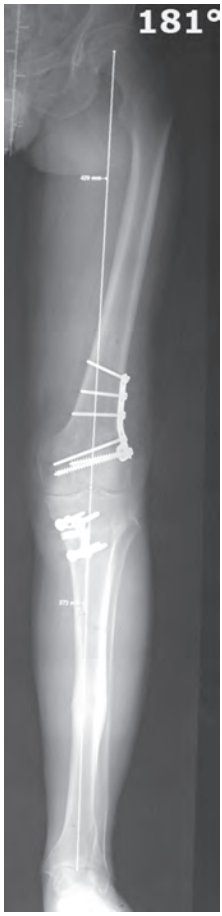

Fig. 4: Standing long leg x-Ray of the case of figure 2 (6 months follow-up).

CONCLUSION

According to these results, computer-assisted double level osteotomy in severe genu varum, is a reliable, reproducible, and accurate technique. This procedure, which is very delicate, especially in reaching pre-operative objectives, is simplified by computer-assistance. The functional results are satisfying and the satisfaction of the patients is very high. Despite the difficulty of the procedure, complications are, in our hands, very rare. We recommend DLO for severe genu varum deformity in young patients to avoid oblique joint line, which will be difficult to revise to TKR.

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HIGH TIBIAL OSTEOTOMY SURVIVORSHIP: OPENING- VERSUS CLOSING-WEDGE

R. BASTOS-FILHO, P. NEYRET

INTRODUCTION

High tibial osteotomy (HTO) is an accepted and reliable option for the treatment of varus osteoarthritis in young, active adults. While HTO typically results in pain relief and improved knee function in 80-90% of patients [1-3], the progression of osteoarthritis often leads to deterioration in the surgical outcome with the passage of time [4-8]. When symptomatic progression occurs, total knee arthroplasty (TKA) is frequently performed. In the 10-year follow-up study reported by Insall *et al.*, TKA was necessary in 23% of patients previously treated with HTO [9].

The two most commonly performed HTO techniques for varus osteoarthritis are medial opening-wedge osteotomy (OWO) and lateral closing-wedge osteotomy (CWO). Closing-wedge HTO has a long history of use in patients with varus osteoarthritis. OWO has gained popularity in recent years because there is no need to osteotomize the fibula and the resulting corrections are considered to be more precise. Significantly fewer data are available regarding the results of opening-wedge HTO, but several authors have reported disadvantages such as donor-site morbidity, lower osteocyte viability (longer time to heal), viral disease transmission, and a more expensive fixation technique. Moreover, weight-bearing is usually allowed later than in CWO. For deformities greater than 10° to 15°, lateral hinge rupture and loss of correction can occur [10]. Other disadvantages are slight tibial lengthening and a low patella. The latter problem is relatively common as demonstrated by biomechanical and clinical studies [11-13].

Although many studies have evaluated HTO, the outcomes of the two types of HTO (OWO and CWO) are unclear. The aim of this study was to retrospectively analyze the results of 141 TKAs performed after HTO and compare the TKA results between CWO and OWO.

MATERIALS AND METHODS

Patients

The prospectively collected TKA registry at our institution was queried to identify TKAs performed after HTO. In total, 2849 TKAs were performed at our institution from 1 January 1996 to 31 January 2012. Of these cases, 141 arthroplasties in 118 patients were performed in patients who had undergone prior HTO for varus osteoarthritis (24 medial opening-wedge and 117 lateral closing-wedge). These 141 cases formed the study group.

Data Collection

For each procedure, data collected prospectively from the TKA registry were obtained retrospectively. Data collected included the pre-TKA and final follow-up International Knee Society (IKS) score [17] and the pre-TKA Hip-Knee-Ankle (HKA) angle. The delay in months between osteotomy and TKA was determined in both groups. Furthermore, we analyzed the relationship between patient age at the time of HTO and the survivorship of this surgery. The HKA angle was obtained from full-length, weight-bearing radiographs in all cases.

Statistics

The S-Plus 8.0 software was used for statistical analysis. A two-independent-samples Student's *t*-test was used to compare the mean time between surgeries for each type of osteotomy. Spearman's rank correlation was used to evaluate the linear association between osteotomy and TKA delay and age at the first surgery. Cox proportional hazards regression was used to analyze the association between the type of osteotomy and the risk of TKA. A *p*-value of 0.05 was considered to indicate statistical significance. Sample means, standard deviations, and ranges were calculated for continuous variables. Because the data were normally distributed, *t*-tests were used to compare the means of continuous variables between the two osteotomy groups. Fisher's exact test was used to compare nominal and categorical variables.

Results

Twenty-four knees (17%) had undergone prior medial opening-wedge HTO, and 117 (83%) had undergone prior lateral closing-wedge osteotomy. Fifty-seven (48.3%) patients were female, and 61 (51.4%) were male. The mean age at the time of the osteotomies was 55.0 ± 9.4 years (range, 22.0-69.0 years), and the mean time from HTO to TKA was 12.2 ± 6.3 years (range, 1.5-34.4 years). The mean patient age at the time of TKA was 67.2 years. The mean pre-TKA IKS knee and function scores were 54.0 ± 16.5 and 60.3 ± 18.3, respectively. The mean pre-TKA HKA angle was 179.5 ± 6.2 degrees (range, 162-197 degrees). At the time of TKA, 68 (48.2%) knees had valgus alignment and 73 (51.8%) had varus alignment. No significant differences between the medial opening-wedge group and lateral closing-wedge group were noted among the pre-TKA measurements, with the exception of the time from HTO to TKA, which was significantly longer in the closing-wedge HTO group (Table 1).

In the CWO and OWO groups, the mean time before TKA was 146.3 months (range, 18.0-413.0 months; SD, 76.3).

The t-test results showed a significant difference in delay between the CWO and OWO groups ($p < 0.0001$) (Table 2). In the OWO group, the mean time before TKA was 88.6 months (median, 80.0; range, 18.0-253.0; SD, 56.5). In the CWO group, the mean time before TKA was 158.5 months (median, 148.5; range, 40.0-413.0; SD, 74.5) (fig. 1).

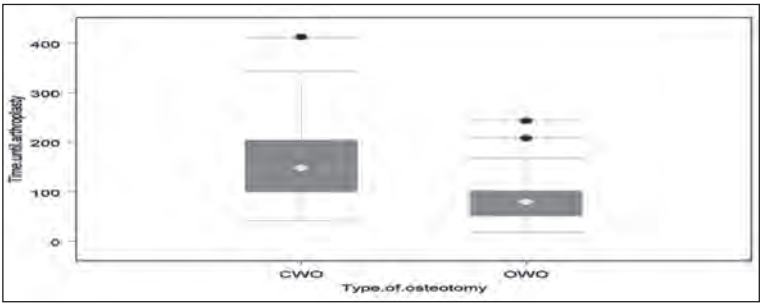

Fig. 1: Box plot showing delay between surgeries according to type of osteotomy.

Table 1: Pre-TKA Comparison of the Opening- and Closing-wedge Groups.

	Opening (n = 24)	Closing (n = 117)	Significance
Age at time of HTO (years)	57.3 ± 7.0	54.5 ± 9.7	p = 0.18
Time from HTO to TKA (years)	7.4 ± 4.7	13.2 ± 6.2	p < 0.0001
Age at time of TKA (years)	64.3 ± 7.6	67.8 ± 9.8	p = 0.10
Sex (percent male)	16/24 (66.7%)	60/117 (51.3%)	p = 0.18
Weight (kg)	80.0 ± 15.1	82.3 ± 16.9	
Body mass index (kg/m2)	27.8 ± 5.1	29.4 ± 5.2	
Patella height (Blackburn–Peele index)	0.79 ± 0.22	0.79 ± 0.32	p = 1.0
IKS Knee Score	56.3 ± 13.6	53.6 ± 16.8	p = 0.40
IKS Function Score	59.4 ± 15.1	60.5 ± 18.6	p = 0.78
Mean Hip-Knee-Ankle angle (degrees)	178.5 ± 6.1	179.7 ± 6.3	p = 0.41
Limb alignment			p = 0.41
- *Varus*	14 (58.3%)	59 (50.4%)	
- *Valgus*	10 (41.7%)	58 (49.6%)	
Extension deficit (degrees)	2.1 ± 4.8	3.1 ± 5.3	p = 0.39
Flexion (degrees)	119.8 ± 14.0	112.7 ± 16.5	p = 0.06

Table 2: Delay from CWO and OWO to TKA (t-test)

	Type of osteotomy		
	OWO	CWO	p-value
Delay between HTO and TKA (months)	88.62 (56.55)	158.55 (74.51)	0.0001

Figure 2 Presents the survival curves for each of the two types of osteotomy. Patients who underwent OWO had a greater probability of undergoing TKA within a certain period of time. The performance of TKA after OWO was almost threefold more frequent (RR=2.91) than that after CWO, and this difference was statistically significant (p=0.0000042). These results were confirmed by performing the log-rank test, which showed that the survival curves of patients undergoing OWO and CWO were significantly different (p=0.00000151).

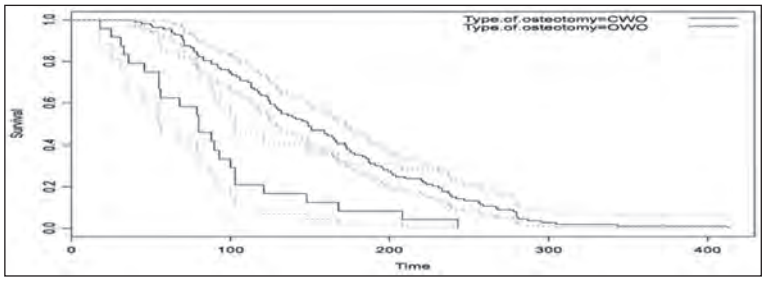

Fig. 2: Hazard regression showing risk of TKA according to type of osteotomy.

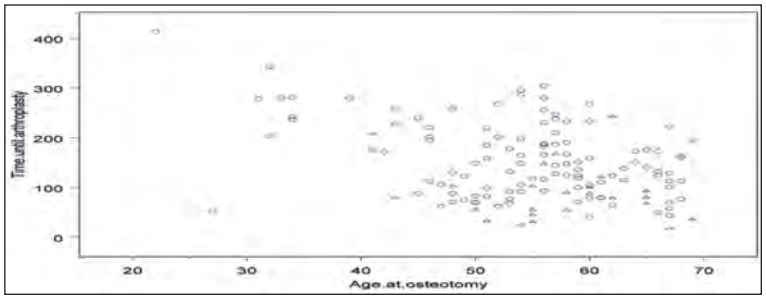

Fig. 3: Osteotomy survivorship according to age. Circles represent closing-wedge osteotomies, and triangles represent opening-wedge osteotomies.

We also identified a significant linear relationship (p = 0.0025) between patient age at the time of osteotomy and the time until arthroplasty. Younger patients exhibited longer osteotomy survival until arthroplasty than did older patients (r = -0.2588318) (fig. 3).

DISCUSSION

The most important result of this study is that the osteotomy surgical technique (OWO or CWO) influences the survival rate of this surgery. To our knowledge, no previous study has compared survivorship between CWO and OWO. We consider this point to be extremely important because the goal of HTO for the treatment of osteoarthritis is to delay the performance of TKA. Thus, a higher survival rate indicates a more effective procedure. Another factor to note is that CWO can be fixed with minimal osteosynthesis hardwire and with satisfactory stability because of good bone contact; thus, the final cost is lower. The reason for the frequency of reversal in the surgical indications for CWO to OWO in the literature is unclear. The latter technique is currently much more common despite its higher cost.

While lateral CWO theoretically distalizes the joint line and increases patellar height [12, 13], clinical evidence indicates that patella infera is actually more common following this procedure [15-17]. This finding may be a consequence of postoperative immobilization and subsequent scarring of the patellar tendon in this population. Opening-wedge HTO also predisposes to patella infera, as demonstrated in several clinical studies [11, 13, 17]. These prior findings were confirmed in our study. Both groups demonstrated a lower overall pre-TKA patellar height.

Insall revised the HTO results between 1960 and 1990 and concluded that younger patients with moderate varus deformity had better results [18]. Our study findings are consistent with this information. We found a linear (p=0.0025) relationship between patient age at the time of the osteotomy and the delay until performance of TKA. Thus, the younger the patient, the greater the osteotomy survival time until arthroplasty (r = -0.2588318). This finding can be explained by the higher bone quality and existing cartilage in younger patients.

A recent study comparing these two osteotomy techniques concluded that the radiographic alignment, functional outcomes, goals, and complication rates were equal in patients who underwent TKA by CWO and OWO.19 However, the survival rates of the osteotomies were not addressed in that study.

This study had several limitations. First, in our comparison of OWO and CWO, we did not compare randomized groups of patients, but rather patients that underwent one procedure or the other for a variety of undefined reasons. Table 1 demonstrates that the groups were

relatively similar in many respects, but it is possible that other unquantified differences between the groups existed, potentially biasing our results. Further, because HTO was performed at a variety of centers for a variety of indications, we lack details about these procedures, which again could reflect group differences for which we did not control. Finally, due to the evolution of the HTO surgical technique over time, the time from HTO to TKA in the lateral closing-wedge group was considerably longer than that in the medial opening-wedge group. The medial opening-wedge group thus exhibited earlier progression to TKA than did the lateral closing-wedge group. This difference could reflect the intrinsic differences between these patient populations, which may influence their outcome after TKA. Only an evaluation of TKA outcomes in patients who were initially randomized to one type of osteotomy or the other can effectively control for these differences.

The conclusions of this study may have been influenced by intrinsic differences between the patient populations as well as variability among the sites and professionals involved in the osteotomy procedures. For this reason, we cannot categorically state that one osteotomy technique is superior to another in terms of survival. This study has the objective to reflect about this subject and future studies with patients initially randomized to one type of osteotomy or another will provide more accurate and definitive results. This will lead to more effective techniques and lower costs.

CONCLUSION

Compared with OWO, CWO was associated with greater survival until performance of TKA. We identified a positive and significant relationship between patient age at the time of the osteotomy and survival.

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KNEE ARTHROPLASTY IN YOUNG PATIENTS. Brazilian Experience

J.-R. PÉCORA

Brazil is still a developing and unequal nation, where some regions stand a high level of development while others remain very poor. There is a large percentage of young people in the population, although a progressive aging is shown by demographic data.

During the 1990's, there was an increase on the number of knee replacement surgeries done in the country, no longer limited to few specialized university centers. Knee surgeons in Brazil indicate knee replacement on patients over sixty, but a great number refuse to undergo arthroplasty even on patients with more advanced age and great functional limitations. Most of these patients would only submit to surgery when the pain is extreme, restricting them to short distance walks.

Knee replacement on young people are indicated mostly in cases of trauma sequelae, common in Brazil due to a large number of traffic accidents (especially with motorcycles), or in cases of rheumatic diseases sequelae, especially rheumatoid arthritis or gouty arthritis and systemic lupus erythematosus.

There is a different approach when it comes to the care and attention given to the patient when performing knee arthroplasty in each of those two situations, and the expectations on the surgery outcome are also different.

In general, patients with severe sequelae of trauma have stiffness of the knee. When undergoing knee arthroplasty, these patients have improvements from the functional point of view even with relatively small improvement of the mobility.

Patients with sequelae due to trauma need special care regarding the surgical incision. There has to be a careful evaluation on factors such as the presence of scars due to soft tissue trauma or to previous surgeries, as well as the adherence of the skin to deep layers. In spite of the severe deformities or bone loss that would justify the indication

of arthroplasty, some patients can be frustrated with the functional outcome, even if the surgeon is able to achieve a reasonable result. These patients expect to have a completely new knee and often overload excessively their prosthesis, limiting its survivorship.

Regarding to rheumatic patients, the indication for arthroplasty occurs in cases that show extensive impairment of joint function by disease severity or lack of proper medical treatment. The most common rheumatic disease is rheumatoid arthritis, but there are also cases of systematic lupus erythematosus and gouty arthritis. Most of these patients chronically use immunosuppressive drugs, which make them

more susceptible to infections. We do not change the antibiotic prophylaxis in these patients, but the surgeon must be aware and consider any sign of infection, in order to treat it early and prevent loss of the arthroplasty.

The multi-joint involvement is very common in all rheumatic patients, so it is imperative to review the entire lower limb before indicating knee arthroplasty, in particular the hip, once the hip is the parameter for positioning the knee prosthesis. Therefore hip arthroplasty must be performed prior to the knee in the event that the two joints are compromised.

Also in relation to the multi-joint involvement in rheumatoid arthritis, special attention must be taken concerning the cervical spine. The manipulation of the cervical spine during general anaesthesia can lead to subluxation C1-C2 due to the involvement of the transverse ligament of the odontoid.

Cases of fixed severe flexing of the knee can be corrected with a surgery prior for the release of the soft tissues and subsequent realization of the arthroplasty later on appropriate time.

Still concerning patients with rheumatoid arthritis, there is greater fragility of the soft tissue and greater osteopenia due to the disease itself and the effect of chronically administered medications. During the surgery, in consequence, there should be more caution when handling soft tissues, particularly in relation to the insertion of the patellar tendon as well as the manipulation of bone tissue in order to avoid fractures or cause increased bone loss.

Patients with juvenile rheumatoid arthritis have very short stature and very small bones. When an indication for arthtoplasty require special unconventional prostheses sized. This is a large demand that challanges the Brazilian orthopaedic surgeon, due to the lack of a industry that provides suitable equipment for the manufacture of this type of prosthesis.

Patients with systemic lupus erythematosus have an even greater soft tissue involvement and a tendency to a much greater stiffness. Most of these patients may have partial pain relief but can verify very little improvement in terms of mobility of the joint, even though the surgeon achieves enough free space to articulate the knee intraoperatively.

Patients with gout tend to have large cavities in bone defects that go unnoticed in radiologic view. The surgeon must be aware of and comply with these defects using bone graft or a revision prosthesis.

In conclusion, the number of knee arthroplasties in young patients in Brazil has increased in recent years but is still very small. Patients with sequelae of trauma or rheumatic disease have needs, care and different expectations for the knee replacement to be considered by the orthopedic surgeon.

STRATEGY: WHICH IMPLANT FOR WHICH PATIENT? SPECIFIC CONSIDERATIONS ABOUT TKA IN YOUNG PATIENTS

Protecting the future: Cemented or cementless

O. COURAGE, V. GUINET, L. MALEKPOUR

Every surgeon aims to safeguard their patient's future. This can be accomplished through two different strategies: keep doing what one has always been doing because it works well, or take some risks to try to make things better. The purpose of this analysis is not to provide an unambiguous course of action; instead we wanted to define the role of cementless total knee arthroplasty (TKA) based on a review of literature. We also wanted to define a set of specifications for cementless TKA.

We are not trying to put cemented TKA – the current gold standard – on trial. It is safe, can make up for imperfections in the bone cuts and has a low rate of loosening over time. In revision cases, there are few surprises except for cemented long stems. But cemented implants have their drawbacks: the rare case of cement-related shock, release of foreign bodies or particles that can cause premature implant wear. The ageing of the cement over the long-term also has some unknowns. And since it takes up and alters the space made by the bone cuts, it can lead to stiffness and pain or alter the alignment. Few of us check the alignment when we apply the cement, even though navigation systems with 0.5° precision are available. Cement (fig. 1) can also cause up to a 2° change in the alignment.

What is the future of cemented implants? An overly easy explantation (fig. 2) reminds us of the possibility of problems at the bone-cement interface.

Fig. 1 ***Fig. 2***

Is resorting to cementless implants the solution? We dream of biological cementing with an integrated implant that does not alter our resected areas. But we all have bad memories of difficult explantations and worrisome lysis around implants secured with screws.

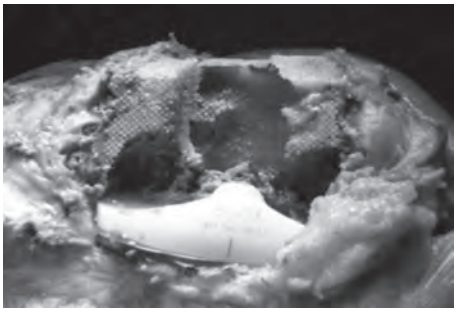

Fig. 3

But before jumping on the cementless bandwagon with respect to these younger patients, it would be prudent to review the published findings.

Over 2000 studies have been published about cementless TKA implants. Gandhi's meta-analysis [1] found no significant differences in terms of outcome scores, but significantly worse rates of loosening and radiolucent lines with cementless implants. However, this study is dated; the patients had more than 10 years of follow-up and most of the implants used at that time were not resurfaced or coated with hydroxyapatite.

It is hard to wait for newer cementless implants to have an equally long follow-up. Radiostereometric analysis (RSA) can help us fill in the gaps. RSA has the ability to detect even 0.1mm of implant migration. The Bart study [2] revealed how important the coating is. Migration after 10 years was 0.79mm for cemented implants and 1.66mm for hydroxyapatite-coated ones, which is not a significant difference. However, uncoated implant migration was 2.25mm.

Julin's study [3] of European practices found that the use of cementless TKA varies between countries, from 3% in Finland to 22% in Denmark. Thus these implants have their place. Some authors have even extended the indications to older patients, with no particular complications [4].

Bone regrowth was extensively studied by Akizuhi, who concluded that hydroxyapatite was essential to the radiolucent lines disappearing after six months.

However, there were notable differences between femoral and tibial components. Many studies have shown no issues with cementless femoral components with more than 10 years of follow-up [6, 7, 8]. More sophisticated RSA studies arrived at the same conclusion [9, 10, 11].

Hydroxyapatite has also been studied. Its characteristics have an impact on the result. It is now recommended that crystallinity greater than 75% and a coating at least 20µm thick should be used [12, 13]. When using a cementless implant, the coating characteristics are important: porosity, pore size, thickness and material. Scanning electron microscopy (fig. 4) reveals the main features of TiGrowth®: porosity of 50%, pore size of 500-750µm, 1000µm thickness and titanium material.

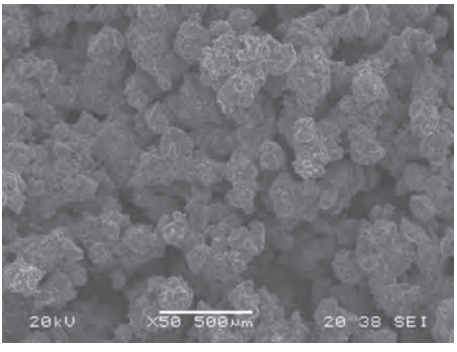

Fig. 4

These various coatings have been studied with precision [14, 15, 16, 17, 18]. They are a critical

factor for achieving good results with cementless implants. Whiteside showed that outcomes with cementless tibial components could be superimposed to those of the best studies involving cemented fixation. However, the tibial component was not highly loaded because a PCL-retaining TKA implant had been used [19].

The stresses placed on the tibial component must be taken into consideration. As such, the HLS system with a 3rd condyle appears to be a promising posterior-stabilised implant because the relatively low contact point generates lower stresses. But to be on the safe side, it is preferable to use a longer stem than the one in the initial system. The few studies that have looked specifically at the tibial component found no significant complications [2].

So what do we recommend to those wanting to use a cementless implant?

Indeed, any proven coating must be included hydroxyapatite (> 20µm). Press-fit is preferred to screw fixation to achieve primary stability. Coating the implant in the cancellous bone area is to be avoided, in case it needs to be extracted later on. Tibial components, especially ones within posterior-stabilised systems, should have a longer keel.

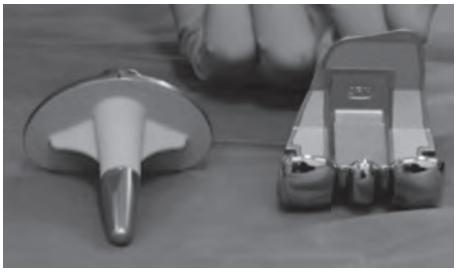

Fig. 5

The implant choice is important, as is the need for instrumentation specific to cementless implantation. The guides must optimise the precision of the cuts (fig. 6). The degree of press-fit required must be quantifiable with accurate jigs (fig. 7).

Fig. 6

Fig. 7

CONCLUSION

These cementless implants can be used in younger patients with similar expectations of survival to cemented implants. On the other hand, there is no clear evidence that patients receiving cementless TKA can resume their activities sooner or have the possibility of going back to more intense sports than those receiving a cemented TKA [21, 22, 23, 24, 25].

Caution is still required, but several recreational activities such as intensive hiking, golf, swimming, and even skiing can be resumed.

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WHAT IS THE OPTIMAL ALIGNMENT IN TKA ?

J. BELLEMANS, J. OOSTERBOSCH, J. TRUIJEN

Restoration of neutral mechanical alignment is since a long time considered as one of the key factors for successful total knee replacement. The fact that neutral mechanical alignment is associated with improved implant durability when compared to knees that have not been restored to neutral, is well documented in literature. Several published series from the eighties and nineties have indeed shown increased polyethylene wear, osteolysis, and implant loosening in knees that were not restored to neutral [1-7]. It is generally accepted that these adverse events occur due to the fact that deviations from neutral mechanical alignment lead to increased mechanical loads on the implant as well as the bone-prosthesis interface, leading to subsequent implant and/or fixation failure.

In recent years however, material properties, polyethylene quality as well as implant fixation have improved significantly, to such an extent that modern TKA might be less subject to these issues that were of concern in the past. Recent literature seems to confirm this [8-11]. Several recent studies have indeed failed to demonstrate an inferior outcome for so-called malaligned versus neutrally aligned knees when modern implants and a contemporary surgical technique was used.

As a consequence of this, the concept of restoring anatomic rather than mechanical alignment has gained interest. In this philosophy the natural alignment of the knee is restored to its original state that was reached at skeletal maturity, before the disease or damage had occurred. The authors have defined this as the patient's constitutional alignment [15].

Such approach would not necessarily restore the alignment to neutral; it was indeed recently demonstrated that a significant number of patients have a constitutional alignment that deviates from neutral. For example, the proportion of individuals with constitutional varus (≥3°) was as high as 32% in males and 17% in females in the author's study [15]. This number may seem relatively high at first sight and underrecognised in the past. The reason for this is that many of the classic alignment studies have been flawed with several shortcomings, such as a limited number of participants, a large variability in the subject's age, recruitment in a hospital setting, lack of stratification and selection bias of the subjects.

Patient's with constitutional varus have since their end of growth always had varus alignment. It is logical to assume that restoring neutral alignment in these patients would feel abnormal

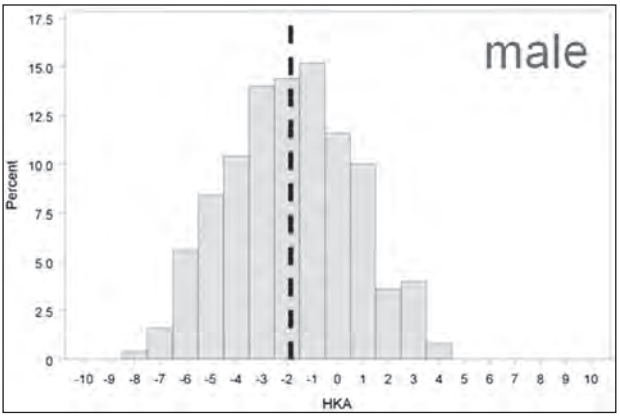

Fig. 1: Histogram depicting the large variability in natural alignment in healthy male individuals, which contradicts the general belief that normal alignment is zero. In fact large variability exists between individuals, and the average alignment in males is around 2° varus.

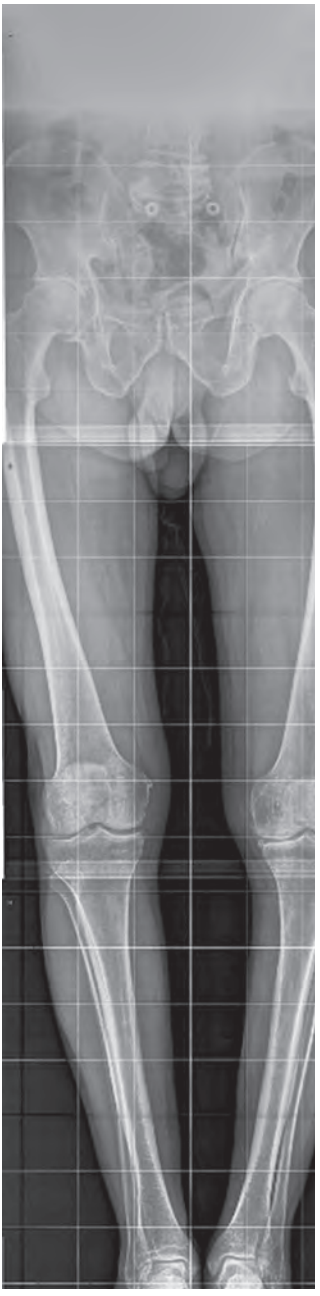

Fig. 2: Typical constitututional varus knee with medial OA (left) requiring knee arthroplasty. The typical characteristics are clearly shown; varus OA of the knee, varus hip neck-shaft angle, varus femoral bowing, and varus of the unaffected leg.

to them, and moreover, this would almost per definition require some degree of surgical medial soft tissue release [14-15]. Restoring the knee to its constitutional alignment by leaving it in in slight varus and in harmony with its surrounding soft issue sleeve could therefore be a more logical option. Recently published studies seem to confirm this [12-14]. Vanlommel et al noted that preoperative varus knees that were corrected to their constitutional alignment did perform better both functionally as well as subjectively when compared to those knees that were restored to neutral mechanical alignment [12].

The debate continues however on which is the most optimal method to restore constitutional alignment. In theory several options exist. One could leave the femoral and/or tibial component slightly undercorrected, or one could aim for full anatomic restoration, including the obliquity of the joint line.

The latter has been popularized as kinematic alignment reconstruction, during which the eroded or damaged parts of the knee are resurfaced to its original anatomic contours. Today it remains however undetermined whether one of these strategies is to be considered superior in terms of functional and

subjective outcome, and whether an evenly durable implant survivorship can be obtained as compared to the classical concept of mechanical alignment restoration [16]. Further clinical research in this domain will be necessary to clarify this.

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CORONAL ALIGNMENT AFTER TOTAL KNEE ARTHROPLASTY: A VICTIM OF PROCRUSTES SYNDROME?

T. LORDING, S. LUSTIG, P. NEYRET

INTRODUCTION

In Greek mythology, Procrustes was a smith and bandit, who tortured passing travelers by forcing them to fit onto his iron bed, by stretching those who were too short or amputating those who were too tall. Today, a "Procrustean bed" describes an arbitrary standard to which rigid conformity is enforced.

A long held tenet in total knee arthroplasty (TKA) is that long term survival and optimal function are dependent on achieving a post-operative limb alignment within 3° of the neutral mechanical axis. To this end, computer navigation and now patient specific instrumentation have been developed, to improve accuracy in implantation and maximize the number of arthroplasties falling within these limits. At the 9^{e} Journées Lyonnaises de Chirugie du Genou in 1999, Rivat and Neyret presented that residual varus of femoral origin was acceptable, but neutral mechanical alignment of the tibial component was mandatory1. More recently, a number of authors have also challenged this principal, suggesting "malalignment" may have little effect on the outcome of knee arthroplasty performed with modern prostheses and techniques.

ANATOMY AND DEFORMITY

To describe the anatomy and alignment of the lower limb, a number of descriptive terms are used. The anatomical axis of each bone refers to a line drawn along the centre of the intramedullary canal. The mechanical axis of the femur refers to a line drawn from the centre of the femoral head to the centre of the knee. For the tibia, the mechanical axis refers to a line between the centre of the knee and the centre of the ankle. The anatomical and mechanical axes of the femur form an angle around 6°, while the two axes of the tibia are usually equivalent.

The angle formed by the distal femoral joint surface and the mechanical axis is referred to as the mechanical lateral distal femoral angle (mLDFA) and is typically 3°, whilst the anatomic lateral distal femoral angle (aLDFA), formed by the anatomic axis and the joint surface, is usually 9°. The tibial joint surface is usually 3° varus to the mechanical axis, and is referred to as the mechanical medial proximal tibial angle (mMPTA).

The global mechanical axis, referred to as Maquet's line, describes a line drawn from the centre of the femoral head to the centre of the talus [2]. Normally, this line passes through the

centre of the knee. The anatomic femorotibial angle (aFTA) describes the angle between the anatomic axes of the femur and tibia, and is usually around 6° of valgus. The mechanical femorotibial angle (mFTA), formed by the mechanical axes of the two bones, is usually 0° or neutral. although variation exists in nature. This is sometimes referred to as the hip-knee ankle angle (HKA).

Care must be taken when performing standardized radiographs for determination of coronal plane alignment. Variance in limb rotation and knee flexion may have significant impact on the observed angles [3, 4].

Deformity affecting lower limb alignment may occur at any level. In general, the closer an extra-articular deformity to the knee, the greater its importance [5].

HISTORICAL EVIDENCE SUPPORTING NEUTRAL ALIGNMENT

In 1977, Lotke and Ecker first examined the correlation between implant positioning and functional outcome in 70 TKAs [6]. Alignment and functional outcome were both evaluated using the author's own 100 point scales. Long leg films were not used and component rotation was not assessed. They noted a significant correlation between good clinical results and good alignment. In four of their five failures, the tibial component was positioned in varus. Denham and Bishop, in a 1978 study of biomechanics in relation to knee reconstruction, defined optimal positioning to be 7°±4° of anatomic valgus for the femoral component and 90°±4° to the anatomic axis for the tibia, to ensure the weight bearing line passed through the centre of the joint [7]. Hvid and Nielsen reported an increased incidence of radiolucent lines at two years surrounding tibial components implanted with more than 4° tilt in any direction, with the interesting exception of varus angulation in osteoarthritic knees [8].

Interestingly, not all studies from this period supported a neutral mechanical axis. Bargren *et al.* reported a failure rate of 2.3% for the Freeman Swanson (ICLH) knee when aligned between 1-5° of anatomical valgus (1-5° varus mechanical alignment), against an overall failure rate of 27% [9].

In an important 1991 study, Jeffrey *et al.* published the results of 115 early Denham knee arthroplasties with median 8 years follow-up [10]. Using long leg radiographs to assess coronal plane alignment, they found a significant difference in the rate of loosening between those aligned within ±3° of Maquet's line (3% loosening) and those outside these limits (27% loosening) (p=0.001). This target range has subsequently been supported by numerous clinical and laboratory studies [11-18].

RECENT EVIDENCE CHALLENGING NEUTRAL ALIGNMENT

In the last few years, several reports have been highlighted challenging the superiority of neutral mechanical alignment.

Regarding survival, in 2007, Morgan and colleagues reviewed the outcomes of 197 Kinemax TKAs at 9 years, and found no difference in revision rate between those in neutral, varus or valgus alignment [19]. In a larger study, Parratte *et al.* published a retrospective review of 398 cemented primary knee arthroplasties performed at the Mayo Clinic using three modern prostheses [20]. Long leg alignment radiographs were performed for all patients pre- and post-operatively. The outlier group comprised 106 knees with post-operative mechanical alignment outside 0°±3°. They found no difference in survivorship at 15 years between the well-aligned and outlier groups, and concluded that describing alignment as a dichotomous variable was of little value for predicting durability. In a similar study of 501 TKAs using a single prosthesis,

Bonner and coworkers found a weak trend towards a higher revision rate in those outside the 0°±3° range, however this fell short of statistical significance (p=0.47). They concluded the relationship between mechanical alignment and survival for primary TKA is weaker than previously reported.

With regards to function, two medium term studies have suggested functional outcome is not adversely affected by residual post-operative varus alignment. From a series of 218 primary TKAs, Matziolis and colleagues compared the results of the 30 knees with the greatest post-operative varus alignment, to neutrally aligned, matched controls [21]. The varus group had a mean post-operative mechanical axis deviation of 6.3° (3.9-10.7°). There was no difference in functional results using multiple validated measures, and no revisions in either group at a minimum five year follow-up. Magnussen and colleagues, from the Centre Albert Trillat in Lyon, examined the results of 553 TKAs for varus osteoarthritis, comparing those with with neutral post-operative mechanical alignment (0°±3°) and those with residual varus alignment greater than 3° at mean follow-up of 4.7 years [22]. They found no difference in *Knee Society Score* (KSS) or revision rate between the two groups, provided the residual varus was femoral in origin. Tibial component varus and femoral component valgus were both associated with inferior KSS results.

One recent study has found superior functional results for TKAs with mild residual varus. In a study of 143 consecutive TKAs for varus OA, Vanlommel et al observed that the 46 knees with residual varus of 4-7° (FTMA 174-177°) demonstrated significantly better KSS and *Western Ontario and McMaster University Osteoarthritis Index* (WOMAC) scores than the neutral and significant varus groups at an average of 7.2 years [23].

DISCUSSION

A number of criticisms have been made of early studies showing decreased survivorship with non-mechanical alignment. Most used only short-leg radiographs for assessment [6, 8, 9] and involved early prosthesis designs no longer in use today [10]. Polyethylene quality was inferior, and sterilization methods were employed now known to cause material property degradation [18].

The literature regarding functional outcome is unclear. Most data comes from studies into navigation in TKA, examining short to medium term results. Some authors have reported improved knee function with more ideal alignment [24-26]. Others have found no improvement and even poorer functional results using navigation [27-30]. A systematic review in 2012 concluded there was improved coronal plane alignment but no functional improvement with navigation [31], however a recent meta-analysis did find improved function in the navigation group [32].

Recently, Bellemans and coworkers have introduced the concept of constitutional varus, suggesting a neutral mechanical axis may be abnormal and even undesirable for many patients [33]. In their study, 32% of men and 17% of women had a natural mechanical alignment ≥3° of varus. Similarly, others have explored they cylindrical axis of the knee [34] and the concept of kinematic alignment [35]. Howell and coworkers reported equivalent or slightly better WOMAC and Oxford knee scores (OKS) for for varus and valgus outlier groups in 198 kinematically aligned TKAs, although this did not reach significance. Dossett *et al.*, in a randomized control trial, evaluated the short term outcomes of 41 kinematically and 41 mechanically aligned TKAs [36]. Whilst the overall limb alignment was similar, the kinematic alignment group had 2.3° more tibial component varus and 2.4° more femoral component valgus. KSS, WOMAC and OKS were superior in the kinematically aligned group. Whilst there were no catastrophic early failures in either study, the long term outcome of kinematically aligned TKA is unknown, and the accuracy of the patient specific instrumentation systems required to achieve kinematic alignment are still being investigated [37, 38].

Contrary to these results, a number of authors have reported inferior results associated with tibial component varus [6, 16, 22, 39, 40]. Berend and colleagues, in a study of a cohort of 3152 knees, found tibial component varus of more than 3° to significantly increase the odds of failure (Hazard ratio 17.2, $p<0.0001$) [16]. In a later study from the same centre on an expanded cohort of 6070 TKAs, Ritter *et al.* found increased revision rates when the tibial component was implanted in varus, when the femoral component was implanted with more than 8° of anatomic valgus, and when one component was implanted to "correct" for malalignment of the other component, resulting in neutral global limb alignment [39]. There was no difference between those with neutral tibial component and neutral overall alignment and those with neutral tibial alignment and overall varus limb alignment, suggesting some residual varus global alignment in itself does not compromise results.

Residual valgus alignment after TKA is associated with inferior results. Karachalios et al found residual deformity to be much more common in valgus knees and associated with significantly inferior clinical results using the Bristol Knee Score [41]. Fang *et al.* reported a revision rate of 1.5% for those with post-operative valgus alignment compared to 0.5% for those in neutral alignment, noting that those with residual valgus tended to fail from ligament instability [42]. Koskinen, in a study of 48 valgus knees implanted with cruciate retaining prostheses, found residual valgus deformity to significantly increase the risk of revision with an odds ratio of 2 (95% confidence interval 1-3, $p=0.025$) [43]. Eight of the fourteen revisions were for progressive medial collateral ligament (MCL) instability. Consistent with these clinical reports, Bryant and coworkers, in a recent cadaveric study, found valgus loading of a TKA to significantly increase lateral tibio-femoral contact pressures and MCL strain [44].

We feel avoidance of tibial component varus and femoral component valgus is crucial for the successful outcome of TKA. As described by Rivat and Neyret in 1999, the origin of deformity is an important consideration in TKA [1]. When the deformity is articular, caused by wear and osteophytes, this may be corrected without asymmetrical bony resection leading to ligamentous imbalance. When extraarticular deformity is corrected, however, asymmetrical cuts will result.

The single tibial cut contributes equally to both the flexion and extension gap. In the case of varus of tibial origin, an asymmetrical cut is required to place the tibial component in neutral mechanical alignment. This leads to medial tightness, which may be balanced with a medial ligament release.

On the femoral side, two bony cuts contribute to the flexion and extension gaps. To correct varus of femoral origin, an asymmetrical valgus distal cut will require internally rotated posterior condylar cuts to balance these gaps (fig. 1). Internal rotation of the femoral component is associated with patellofemoral complications, pain, and increased failure rates [40, 45, 46]. Considering the origin of femoral varus deformity is often the proximal femur, we feel it is best to accept a degree of femoral component varus rather than risk imbalance and component internal rotation.

Furthermore, tibial component varus and femoral component valgus in a globally well aligned knee will result in joint line obliquity. Increased joint line obliquity is known to cause increased shear forces after osteotomy [47], and experimental data have supported this in TKA [15]. Interestingly, a recent report found coronal joint line orientation was not affected in subjects with constitutional varus [48]. The clinical implications of this finding have yet to be studied.

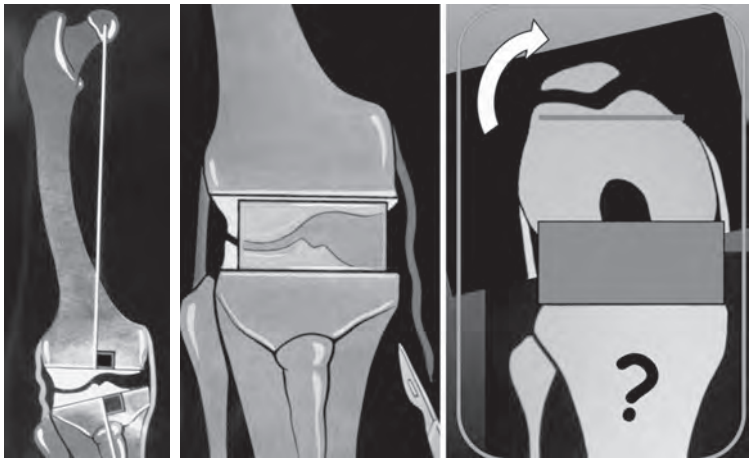

Fig. 1: Asymmetrical distal femoral cut required to correct varus of femoral origin. To balance the extension gap requires internal rotation of the femoral component.

CONCLUSION

As noted by Tew and Waugh in 1985, although coronal alignment is surely a factor in the outcome of TKA, it may not be the most important factor and may serve to compound failure from other causes [49]. Other technical factors, such as sagittal and rotational alignment, joint line restoration, and soft tissue balance all influence the final outcome. The ideal alignment for patient function and prosthesis longevity may in fact be different. If so, advances in materials technology may allow for implant survival in a non-optimal mechanical environment. Whilst mild residual global varus deformity may not negatively impact outcomes, it is important to avoid varus of the tibial component and valgus of the femoral component.

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PREOPERATIVE PLANNING. WHAT I DO BEFORE A UKA

T. AIT SI SELMI, C. MURPHY, M. BONNIN

INTRODUCTION

The functional benefits of the Unicompartmental Knee Arthroplasty (UKA) have been firmly established [22, 25, 33] and excellent long term results have promoted increased interest for this form of treatment [23, 31]. However, UKA failure often requires revision to TKR, which may include revision implants, and this does not give results comparable to a TKR performed as a primary procedure [11, 35]. It is important that the UKA is neither perceived nor proposed as a temporary prosthesis, nor as a conservative treatment option. The UKA must be envisaged as a treatment rivalling TKR for durability. Pre-operative work up is vital to reduce the potential causes of failure associated with improper indications. Technical errors and failures due to implant or material failure are dealt with in a separate chapter.

The classic indication for UKA is isolated unicompartmental osteoarthritis (OA), in the absence of severe patellofemoral wear, and with an intact ACL [18, 20]. Equally age, weight, mobility status, level of sporting activity and lower limb alignment should be taken into account, in addition to indication for the prosthesis. For teaching purposes, we will deal with knee-related factors and patient-related factors separately.

KNEE-RELATED FACTORS

The Femoro-Tibial Compartment

The most frequently encountered pathology affecting the femoro-tibial compartment is OA, in particular early OA, before the neighbouring compartment have been affected. A unicondylar prosthesis is appropriate for Stage II or Stage III changes, according to the Ahlback Classification, i.e. it is suitable for complete narrowing of the femoro-tibial joint line, or a wear-induced bony cupping of up to, both no than 5mm [23, 30, 36]. Conversely, the patient with only partial narrowing should be steered towards useful adjunct treatments, as a higher rate of failure has been reported in the absence of documented complete joint line narrowing [29]. There is no difference whether the arthritis is primary or secondary to a meniscetomy.

The diagnosis of isolated unicompartmental OA is based primarily on standard AP and lateral x-ray weight bearing views (fig. 1). Additional axial views of the patella allows the elimination of radiographic patello-femoral wear (fig. 2). Clinical examination in association with stress views should demonstrate a reducibility of the deformity in the frontal plane, with radiographic early and isolated arthritis without loss of the central pivot (fig. 3).

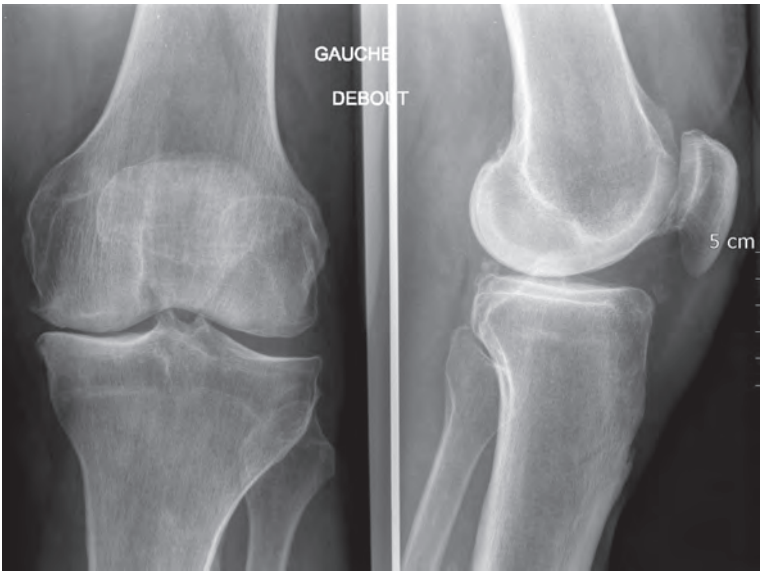

Fig. 1: Typical medial femoro-tibial OA on AP and lateral standing views.

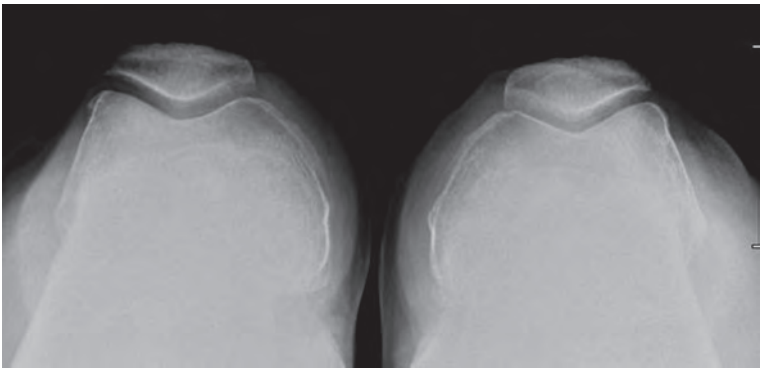

Fig. 2: Typical skyline view were patello-femoral joint is well aligned without cartilage wear.

Osteochondral lesions or necrosis of the femoral condyle, and much less commonly of the tibia, is a recognised indication for surgery, as long as there is sufficient bone stock to accommodate a prosthesis. These should be differentiated from fatigue fractures, which can be challenging in the early phase. Serial imaging is useful in clarifying this situation.

Meniscal calcifications or chondrocalcinosis of the opposite compartment is not a contra-indication [13]. Global wear, as seen in the inflammatory arthritides, is generally accepted as a firm contra-indication [23].

Post-traumatic deformities are contraindicated, with the exception of isolated collapse of a lateral tibial plateau fractures, wich results in an intra-articular deformity [21, 36] (fig. 4).

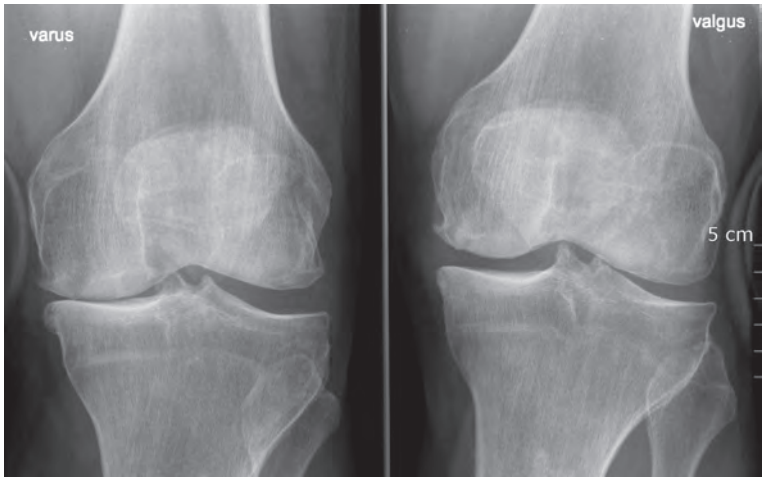

Fig. 3: Varus and valgus stress x-rays showing the absence of lateral laxity and the reducibility of the medial join space.

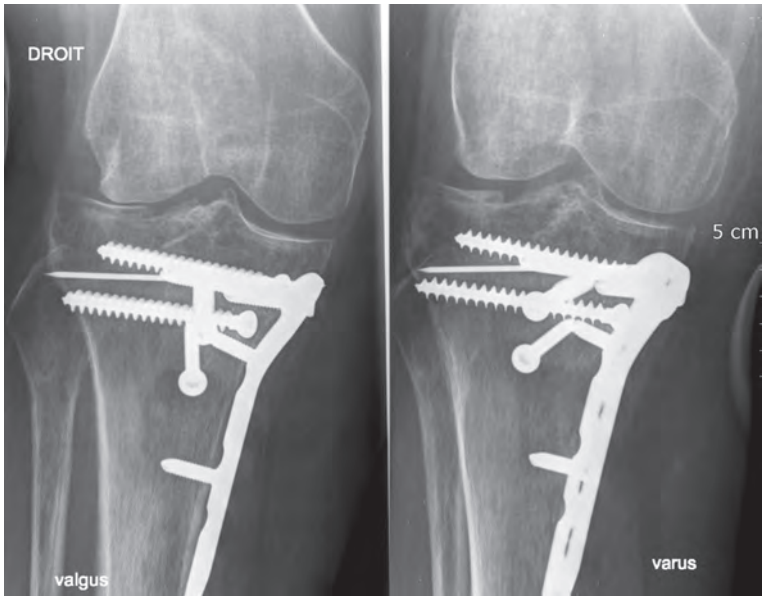

Fig. 4: Lateral post-traumatic OA. Reducibility of the deformity is shown on varus stress X-ray (right) and absence of concomitant medial laxity is assessed on valgus stress view (left).

The Patello-Femoral Compartment

By definition, implanting a unicondylar knee prosthesis does nothing for a badly worn patello-femoral joint (PFJ) articulation, and an implant in this situation will likely lead to failure [5]. Symptoms such as anterior knee pain after periods of immobility or on descending stairs are useful to distinguish the source of discomfort, but the link between symptoms and radiographic destruction of the PFJ has been questioned by some authors [4]. In reality, identifying the

condition of this third compartment is easily done on axial radiographs, but even established wear in this joint is rarely considered a contraindication to UKA (fig. 5). Beard *et al* suggest that patellar or trochlear wear seen intra-operatively has no bearing on outcomes [4]. In addition, complete narrowing of the lateral joint line or the presence of large osteophytes will influence post-operative pain. For Munk *et al.* [27], although PF wear is not a factor that influences outcome, pre-operative lateral patellar subluxation is associated with failure.

Patellofemoral lesions, although not a contra-indication per se, can be managed with additional procedures (such a resection of osteophytes, a lateral facetectomy of the patella, or resection of bony spurs on the patella) at the time of surgery for UKA (fig. 6). Medial PF lesions, although rarer, do not appear to affect outcome adversely.

The Ligaments

The presence of arthritis secondary to chronic ACL laxity is recognised by a majority of authors as a contra-indication [9, 23]. Clinical assessment is paramount, but in the situation where there is already cupping of tibial condyle things are not so clear cut. X-rays which demonstrate significant osteophytes at the intercondylar notch signify a damaged ACL whose function has been affected. Translation which fails to reduce also signifies ACL rupture. Single leg weight-bearing lateral views are helpful, showing posterior cupping and spontaneous tibial translation (fig. 7).

Rarely, peripheral lesions are noted, often in a post-traumatic setting. These are seen clinically, further assessed on stress views, and represent a contra-indication for surgery.

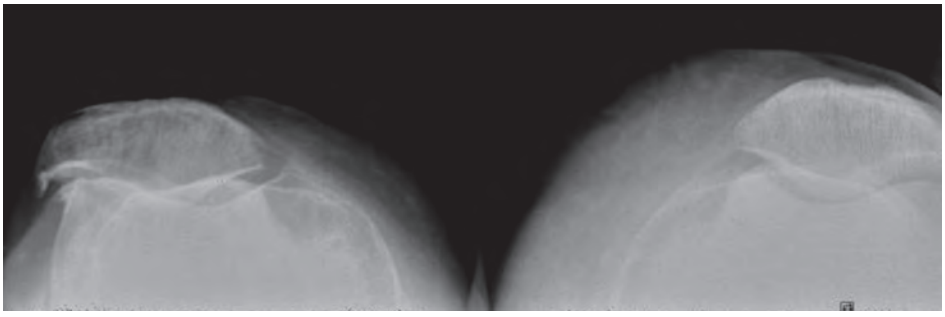

Fig. 5: Skyline view showing a patellar lateral OA and with a typical osteophyte of the right knee.

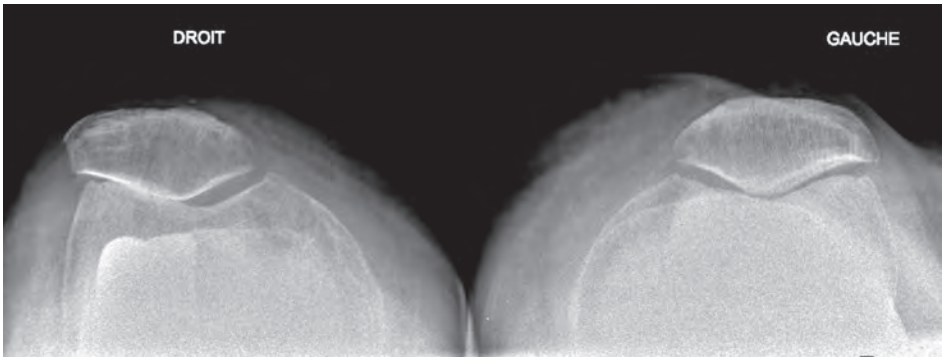

Fig. 6: Post-operative skyline view of the right knee after lateral facetectomy (preoperative view on figure 5).

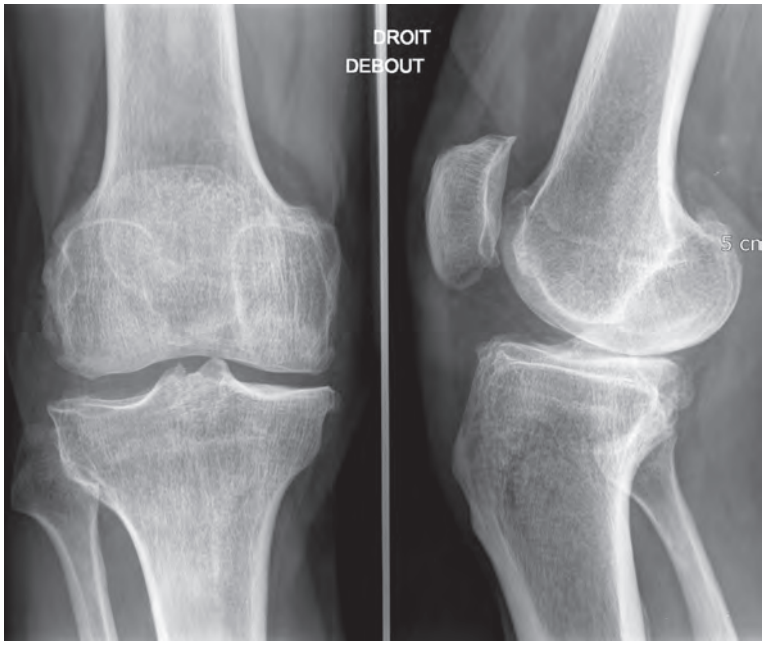

Fig. 7: Medial OA resulting from previous anterior cruciate ligament rupture with a major spontaneous anterior tibial translation on lateral weight bearing view.

MRI screening

In addition to clinical examination and x-rays imaging, MRI is very useful and is used systematically in our service. First MRI allows an objective measurement of cartilage in the opposite compartment. For Yamabe *et al.* [42] conventional imaging overestimates the degree of cartilage damage, and retrospective MRI assessment could have increased the number of eligible patients from 2.3% to 58.6%. Hurst meanwhile [16], found that abnormal pre-operative MRI findings do not influence of the outcome of UKA when modern radiographic and clinical criteria are met, suggesting that lesions on MRI might be over-estimated. The MRI allows as well the screening of potential meniscal lesions of the other compartment which is missed on standard screening [26].

Clinical examination and radiological assessment of the PFJ are significantly improved while combined with the MRI according to Waldstein [41].

Assessment of the ACL ligament is useful. Hill [14] cites a complete ACL rupture rate of 22% among the cohort of arthritic knees examined. Nevertheless, the macroscopic appearance can be balanced by the histological assessment [39].

Arthritis secondary to chronic laxity must be differentiated from an arthritis that is caused by progressive ACL attrition or cysts due to notch intrusion and collagen degeneration (fig. 8-10). For these cases, no spontaneous tibial translation is seen and ligamentous lesions are often incomplete as seen on the MRI. In our experience, MRI correlates well with the intra-operative macroscopic appearance once the notch osteophytes have been resected (fig. 11 & 12). In this particular context, the indication for the Unicondylar prosthesis is acceptable.

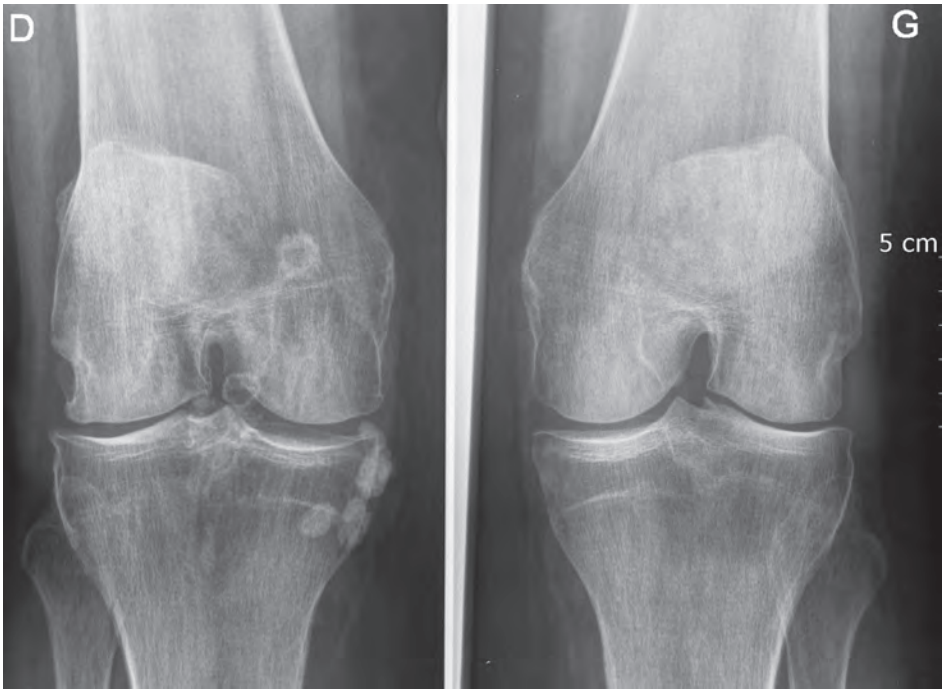

Fig. 8: Lateral OA with a narrowed inter-condylar notch.

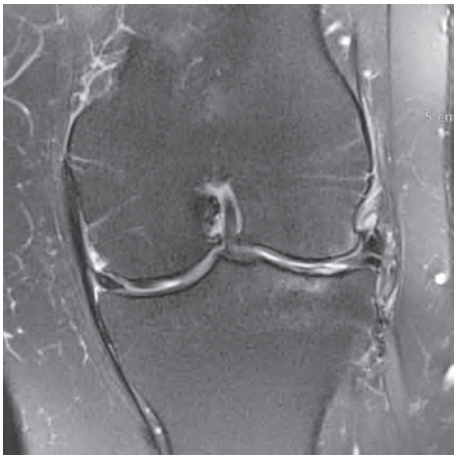

Fig. 9: MRI showing ACL fibres engulfed in osteophytes of the inter-condylar notch (X-Ray on figure 8).

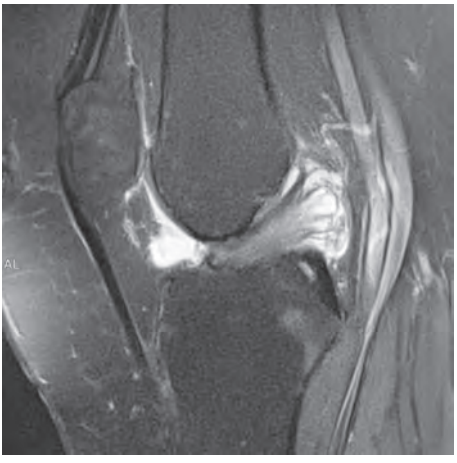

Fig. 10: MRI showing a degenerative ACL cyst. Note that the anterior ligament bundle is clearly seen.

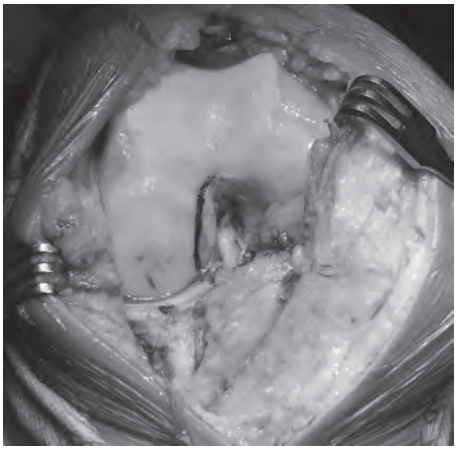

Fig. 11: Lateral inter-condylar notch osteophyte rubbing against the ACL.

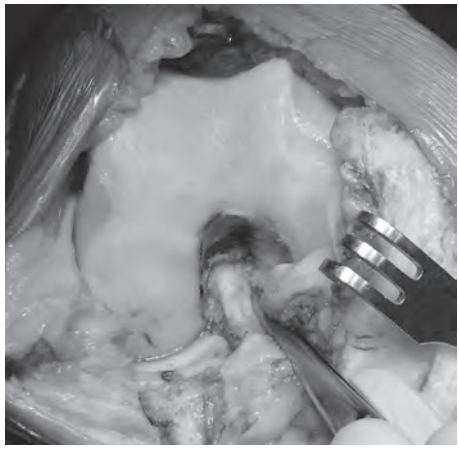

Fig. 12: Re-evaluation of the ACL after notchplaty showing a solid and functional aspect of the ligament.

Limb Alignment

Excessive axial deformity of the femoro-tibial mechanical axis threatens survivorship of a UKA, due to excessive demands on fixation or due to premature polyethylene wear. Ideally, alignment of the FT axis is corrected by the prosthesis, restoring the original deformity of that knee. This "native deformity" or alignment normally corresponds with an under-correction sought at the end of the procedure, as opposed to the 180 degree reference which is, for many surgeons, the target for TKR. The pre-operative deformity, when measured by goniometry, combines both the native malalignment plus the intra-articular wear, but it remains the measurement of choice by tradition (fig. 13).

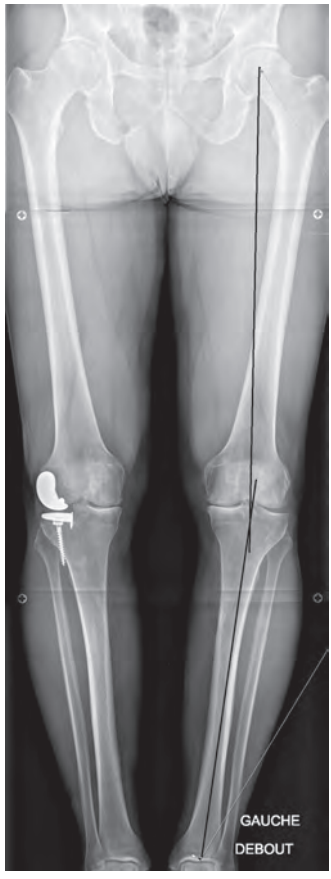

Fig. 13: Long legs film showing the global deformity of the left knee. Femoro-tibial angle is of 7° of varus.

For insertion of a medial UKA, 5° to 7° of true varus is acceptable (on corrected views), corresponding to a 10° deformity on pre-operative goniometry [7, 10, 12]. For the lateral compartment, an upper limit of 7° of post-reduction valgus is the upper limit, corresponding to 12° of uncorrected valgus [31, 36]. Some authors have proposed wider inclusion limits, judging deformity in the context of the weight of the patient [6]. Gulati *et al.* [10] propose that axial deformity should not have an upper limit, but should always be restored, without affecting clinical outcomes or durability of implants. It is important to note that reducibility should be quantitative – showing satisfactory re-alignment, but also qualitative, as judged by a repositioning of the tibia in line with the femur.

Tibial slope can be considered under the category of saggital alignment. Reproducing the slope is the aim with the UKA, to accurately restore knee kinematics. Tibial slopes greater than 10° are associated with poorer results, and normally considered a contra-indication to surgery. When weight-bearing the tibial slope determines anterior tibial translation, and contributes to constraints on the posterior aspect of the tibial plateau. Potential consequences for an increased slope include early polyethylene wear, fatigue rupture of the ACL [12] and progressive risk of tibial plateau collapse [1].

Range of Motion

The presence of an established restriction in flexion or a limitation in extension frequently translate to marked OA changes, and contra-indicate using a unicondylar knee prosthesis. 10°-15° of flexion contracture, and extension no greater than 100° are considered threshold values [3, 31]. In cases where the cause of stiffness is extra-articular, this contra-indication becomes a relative one. It is important to counsel such patients that their restriction in ROM will persist after surgery.

PATIENT FACTORS

Age

For most authors the ideal age for considering a UKA is, like most arthroplasty, between 60-65 years old [7, 23]. For older patients – over 80 years old – there are concerns regarding the quality of bone for such an implant, and these patients are associated with a higher risk of medial tibial plateau collapse, especially in the context of established osteoporosis [1]. The risks of using a UKA must be balanced against what is a significant benefit for such frail patients – the reduction in the magnitude of the surgical insult. The older the patient, the higher the likelihood that technical faults or ancillary-related difficulties will cause bony collapse [34]. For younger patients (those under 65 years old) a legitimate alternative is a tibial osteotomy. Despite this, the improved quality of implants and in particular encouraging clinical outcomes have led to surgeons reduce the age at which they would consider a UKA. Certain authors have demonstrated survival rates equivalent and superior to osteotomy for sporting activity and for quality of life [15, 30]. Despite this, the higher rate of revision in patients under 65 years old reported by national registries should temper this enthusiasm [40]. Finally, revision of UKA to TKR remains a relatively straightforward option which gives better results than either TKR post HTO or revision of TKR to TKR. This makes consideration of UKA a strong argument for a younger patient for whom the prospect of a revision procedure is to be expected regardless of the index intervention [17, 19]. For younger patients revision of UKA to UKA, or isolated change of polyethylene are manageable interventions assuming that serial observations and follow up continue and reveal no evidence of aseptic loosening [30].

Weight and size

Although recent publications have questioned weight as a limiting factor consensus for the

upper weight limit is around 90kg [1, 31]. Others use the BMI metric to take into account body habitus, with larger patients requiring larger prostheses to tolerate the increased mechanical loads; the upper limit using this criteria is a BMI of 32-35 [6].

Gender

Females are disproportionately well represented in the UKA registries on account of their lighter body weight. The higher association of females with osteoporosis can be considered counterpoint to this. However, apart from the weight-related arguments, gender does not seem in itself to be an exclusion criteria.

Sporting Activity

Traditionally, patients who are engaged in higher levels of sporting activity are directed towards an osteotomy. The increasing involvement of all age groups in sport, and the feasibility of UKA for active patients has led to this technique being offered to patients who are involved in lower impact sports such a golf (preferably for the trail leg), swimming, boules/pétanque and tennis [8, 15]. It is imperative these patients receive regular surveillance to monitor polyethylene wear.

DISCUSSION

The eligibility for a UKA is related to the quality of the screening and can vary according to the surgeon's view [2]. The typical indication for UKA is for a patient under 65 years old, with Stage II or III OA, where pain is localised to one compartment, the knee has a good range of movement and where the weight of the patient does not exceed 90kg. Reducibility of the deformity must be verified clinically and radiologically with stress-views. The views confirm that the main deformity is intra-articular. Goniometry should document the femoro-tibial axis does not exceed 10° varus or 15° valgus. Axial views should show at most some remodelling of the PFJ. Finally, the presence of a healthy central pivot is checked clinically, and confirmed radiologically by a lack of spontaneous translation on the AP weight-bearing views [9, 12, 23].

Due to the high prevalence of medial joint wear, medial UKAs are far more common than lateral UKAs. Recent studies though have emphasised the benefits of the lateral UKA [3, 31]. Selection criteria are essentially the same, but with two subtle differences. Firstly, valgus deformity in the axial plane may be higher – up to 7° – as opposed to 5° for the medial joint. Secondly, PFJ involvement relates predominantly to lateral femoro-patellar narrowing, which is more acceptable, and easily treated with a simple additional intra-operative procedure. Lateral tibial plateau fractures constitute a novel indication for lateral UKA.

For knees with advanced arthritis in whom the deformity is only partially reducible, and which are showing early changes in the other compartments, but which still have a functional ACL, use of a UKA can be considered, but only for patients that are very frail, elderly, with significant cardio-vascular or thrombo-embolic co-morbidities, or those patients whose axial deformities exceed the recommended limit of 5°-8° (fig. 14 & 15). It is vital that clinical history and examination correctly identifies the cause of pain, and that clinical signs correlate with the affected femoro-tibial compartment. The aim of achieving "a forgotten knee prosthesis" should be superseded by giving the patient comfort, and allowing them regain their autonomy [24]. Finally, Slower *et al.* highlight the economic argument for offering these patients a UKA [37].

Although a deficient or incompetent ACL is in principle a strict contra-indication for UKA, some success with ACL reconstruction combined with UKA have been reported in the short term [28, 38]. This seems reasonable, as long as the arthritis is due to the ACL rupture and there is no significant malalignment. This is only feasible when there is no significant tibial cupping, and when tibial translation is still reducible. This saggital reducibility can be

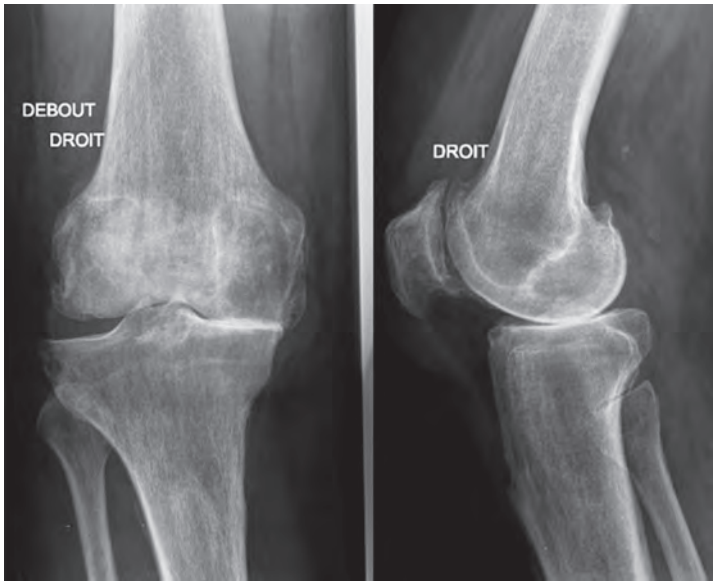

Fig. 14: Grade 4 medial OA in an 80 years old female patient.

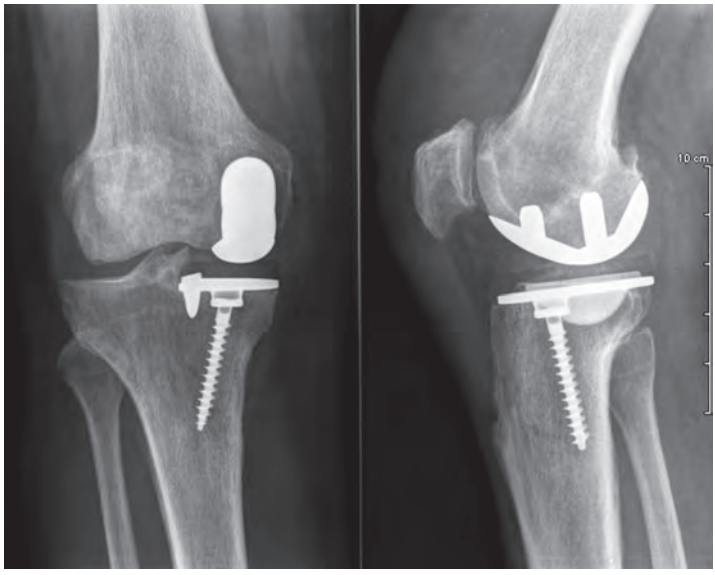

Fig. 15: Post-operative X-Ray demonstrating a good realignment and the absence of anterior translation despite a torn ACL. Note that the tibial slope has been kept neutral.

gauged by single leg weight bearing lateral x-rays showing no spontaneous tibial translation. On the other hand, for very elderly or frail patients for whom a TKR would be an excessive risk, it might seem reasonable to offer a UKA for the ACL deficient patient, taking care not to leave an excessive tibial slope, which would cause premature polyethylene wear. Younger patients at least have the option of either osteotomy with or without ACL reconstruction.

For the most part, failure of osteotomy (the most frequently performed of which is a valgus-inducing tibial osteotomy) rules out the choice of UKA on account of poor results and poor functioning of the knee joint. However while failure of HTO is related to incorrect deformity correction (usually under-corrected), and when all other criteria have been met, UKA can be considered [32]. This remains a soft indication, and a further osteotomy or indeed a TKR should also be discussed.

CONCLUSION

While clinical and radiological screening must be robust, and must allow appropriate indications to be identified, it is important to insist on contribution of the MRI imaging. Apart from careful examination of the knee itself, analysis of the patient allows fine-tuning of the indication for UKA. In any event, appropriately defined selection criteria should allow a UKA to be considered not as a random and temporary solution but one which is selected as the best performing option and more often than not, the definitive one.

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WHAT ARE THE LIMITS FOR UNICOMPARTIMENTAL KNEE ARTHROPLASTY? 10 top tricks for an ideal UKA

S. ROMAGNOLI, M. MARULLO; M. CORBELLA

Unicompartimental knee replacement (UKR) has several well-known advantages over total knee replacement (TKR): less invasiveness, tissue sparing, respect of both cruciate ligaments and consequently respect of native knee kinematic, better knee function and less morbidity [1-3]. Historically, UKR survivorship was lower than TKR one [1, 4].

This was caused by wrong indications, partial knowledge of knee kinematic, inadequate components designs and poor surgical technique.

To obtain a successful UKR, I've identified 10 top items to apply during UKR surgery.

TIBIAL AND FEMORAL CUTS

The native orientation of the tibial plateau should be respected. On the coronal plane, it is perpendicular to the epiphyseal axis of the tibia, not to its diaphyseal one. Moreover, the two compartments have different obliquity in the sagittal plane (slope) [5-7].

Because UKR necessitates of anterior cruciate ligament (ACL) integrity, the native tibial slope should be respected to obtain a normal knee kinematic and not to overload or slacken the ACL. Consequently, tibial cut should be done according to the native orientation. The coronal orientation of the tibial cut must be perpendicular to the epiphyseal axis of the tibia, not to the whole axis of the tibia, in order to respect the height and obliquity of the joint line and avoiding any consequent release. In the sagittal plane, the cut should be 0-3° for the lateral compartment and 3-6° for the medial one.

The femur should be cut as less as possible because UKR must be considered as resurfacing replacement. The thickness of the femoral component we use is 2mm. So, we remove only 2mm of cartilage and bone from the femur. Femoral cut must be very conservative in the lateral compartment because of condylar hypoplasia in the valgus deformity. In this case, the thickness of the lateral condyle should be restored using a thicker femoral component. This tip will correct axial alignment and joint line obliquity.

TIBIAL COMPONENT DESIGN

The tibial plateau is different from medial to lateral. Its lateral part is semicircular, its medial one is asymmetrical instead, wider posteriorly than anteriorly [8, 9].

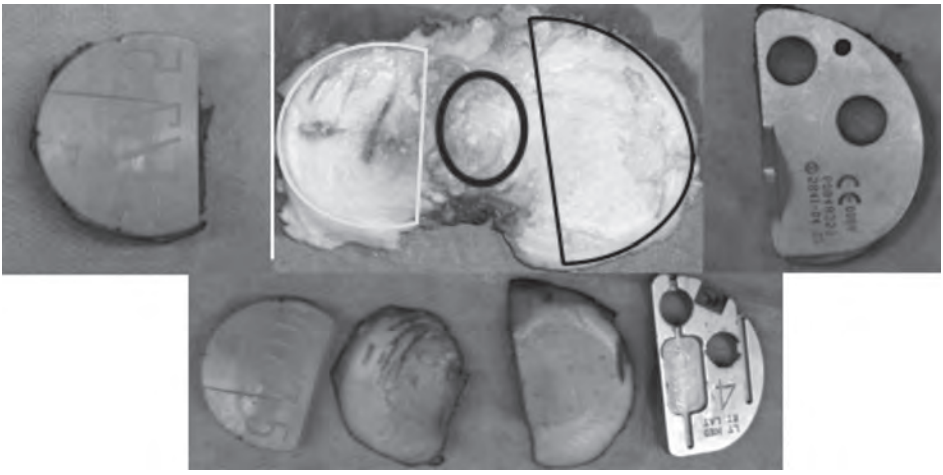

Fig. 1: The medial and lateral parts of the tibial plateau have different shapes which can be replaced adequately only with dedicated tibial components.

This asymmetry between the two parts of the tibial plateau can be managed only using dedicated tibial components for the medial and the lateral compartments (fig. 1). We use a semicircular tibial component for the lateral compartment and an anatomic component the medial side. This is the unique way to closely adapt the prosthesis to native anatomy.

POSITION OF THE FEMORAL COMPONENT

The position of the femoral component should be ideally perpendicular to the center of the tibial component during both flexion and extension in order to achieve more surface contact and avoid peak wear. Till 10° of obliquity in flexion are acceptable. To obtain it, surgeons must keep in mind that at the last 20° of knee extension, external rotation of the tibia occurs and locks the knee (position of maximal stability) [10, 11].

Consequently, a centered femoral implant in flexion may lead to an excessive internal rotation in extension and impingement on the tibial spine eminence. Therefore, the positioning in flexion should exaggerate the lateral rotation and the lateral positioning. In the lateral compartment, this should be obtained even retaining lateral osteophytes.

Moreover, femoral component orientation should follow the condylar axis (fig. 2).

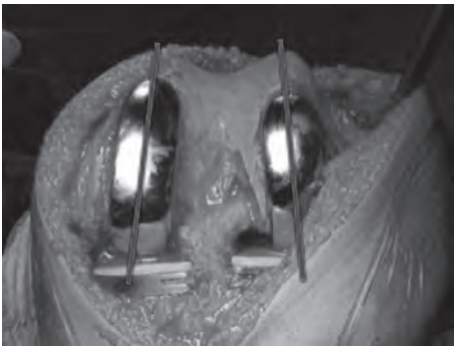

Fig. 2: The femoral component should be placed as lateral as possible and along the axis of the femoral condyles.

CORRECTION OF FLEXION DEFORMITY

Many surgeons consider flexum deformity as an absolute contraindication for UKR. Before evaluate flexum as irreducible and consider TKR as the unique solution, some tips should be performed.

First of all, evaluate it under anesthesia. Often flexum is only a consequence of knee pain. After that, give space to the ACL! Removing any osteophyte from the notch will free the ACL. Then, remove any posterior osteophyte. This should be done after tibial and femoral cut to obtain enough space for working posteriorly.

After component trial position, range of motion should be tested. If some degrees of flexum are still present, a dosed elongation of the knee flexors should be done. To do this, no surgical acts should be done. A gentle manual stretching is enough. This procedure takes time because the knee should be maintained in hyperextension for some minutes, but it is very effective.

UNDERCORRECTION OF THE DEFORMITY

Tibio-femoral wear in knee osteoarthritis (OA) often causes varus or valgus deformity. The location of tibio-femoral wear (medial or lateral compartment) is often a consequence of the morphotype [12].

A native valgus knee can develop lateral OA, a native varus knee can develop medial OA. Osteoarthritis worsens the amount of the deformity, and this fact should be considered in UKR. The tibial and femoral cuts should be done in order to correct the deformity caused by cartilage wear, not the one determined by the morphotype. The aim is to respect the joint line. Postoperative mechanical axis should be hypo-corrected, proportionally to preoperative deformity and constitutional varus-valgus (fig. 3). This shrewdness will not alter the native knee biomechanic and will not cause overstress on the opposite compartment.

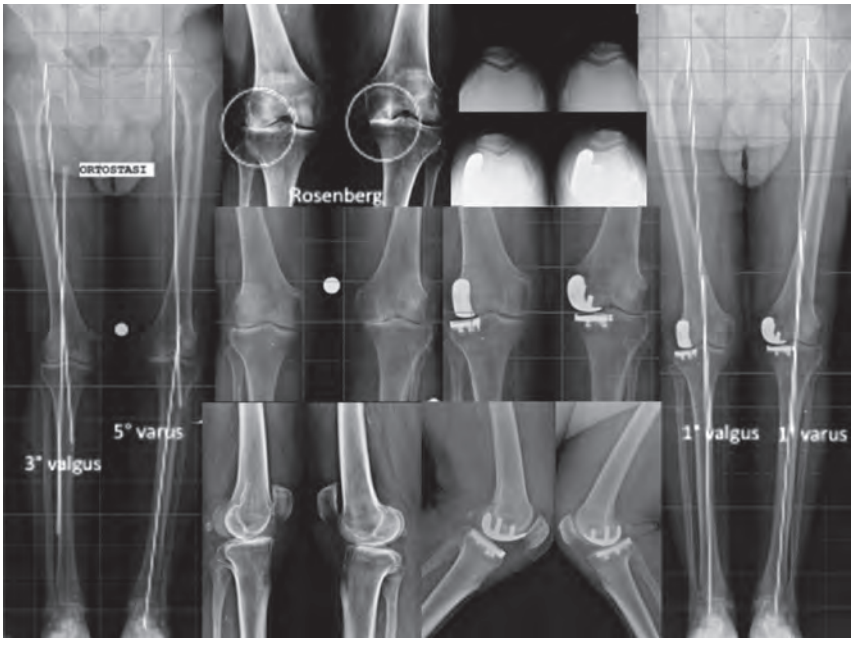

Fig. 3: 83 years old man with right knee lateral OA and left knee medial OA. He had simultaneous bilateral UKR. Postoperative X-rays showed undercorrection of the coronal deformity to respect the native morphotype.

PREPARING COMPONENTS ALLOCATION

A proper cementing technique is necessary to obtain a successful UKR. Resurfacing led to a minimal amount of bone removed from the tibial and femoral side. Consequently, the prosthesis components have to lie on subchondral bone, which is often sclerotic. To permit a deeper penetration of the cement in the cancellous bone, the subcondral bone has to be prepared by drilling and sawing it, superficially and perpendicularly to the cutting surface. This shrewdness will improve cement adhesion and prosthesis stability.

CONSIDER THE PATELLO-FEMORAL JOINT

In performing an isolated UKR, the patello-femoral joint should be always carefully evaluated [13, 14].

We developed an algorithm to recognize when performing patello-femoral replacement (PRF) in association to UKR. 3 main criteria and 2 secondary criteria formed this algorithm.

The three main criteria are: patello-femoral pain; patellar malalignement or lateral patello-femoral wear on X-Rays axial view; intraoperative findings of grade 3-4 patello-femoral chondral degeneration. The two secondary criteria are: female sex and body mass index (BMI) >32 (fig. 4).

If 2 main criteria or 1 main criteria and 2 secondary ones are present, isolated UKR will fail and UKR+PFR must be considered (fig. 5).

CONSIDER BOTH TIBIO-FEMORAL COMPARTMENTS

Most surgeons consider small implants useful in unicompartimental OA. In patients with high functional demand and knees with no major deformity and an efficient anterior cruciate ligament, bi-compartimental OA should be addressed with bi-unicompartimental knee replacement (fig. 6) [15-16].

Even when surgery starts for unicompartimental replacement, the opposite compartment should be evaluated. If extensively degenerated, surgeon should be ready to perform bi-UKR.

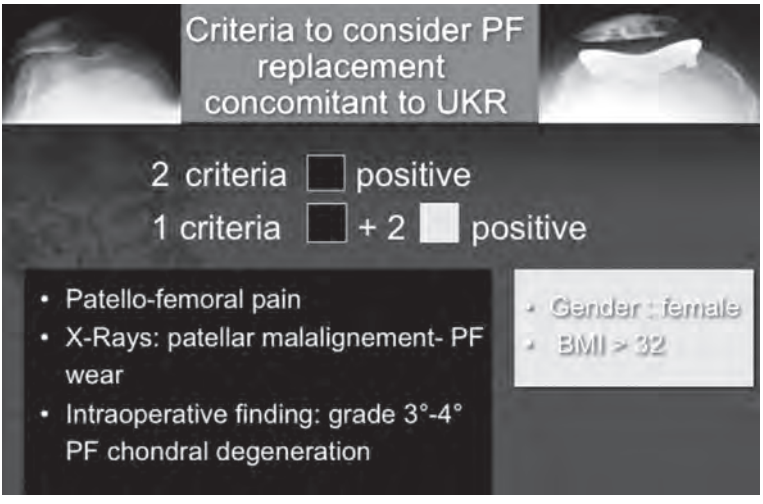

Fig. 4: Algorithm to consider concomitant PF replacement associated to UKR.

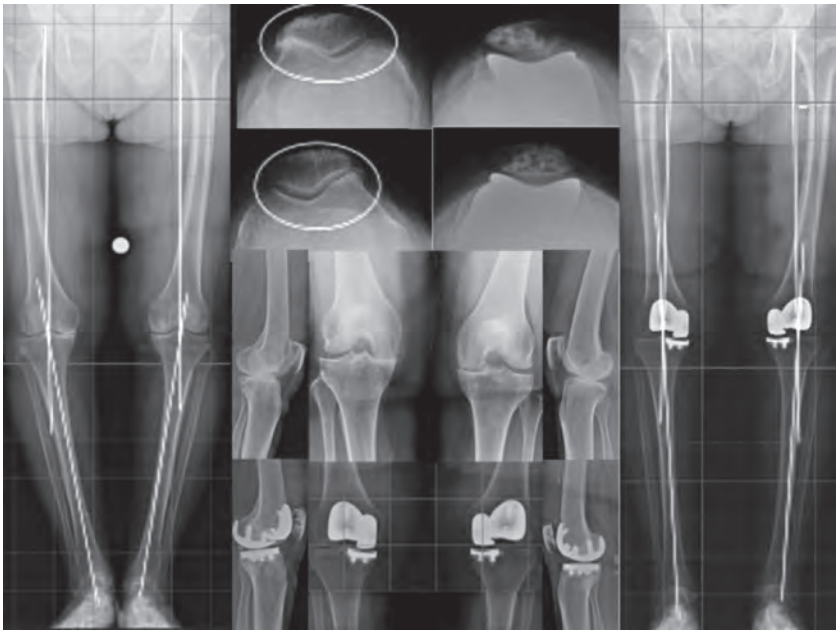

Fig. 5: 63-years old woman with bilateral medial OA, lateral patello-femoral wear, patellofemoral pain and BMI=33.4. She had successful bilateral UKR + patello-femoral replacement.

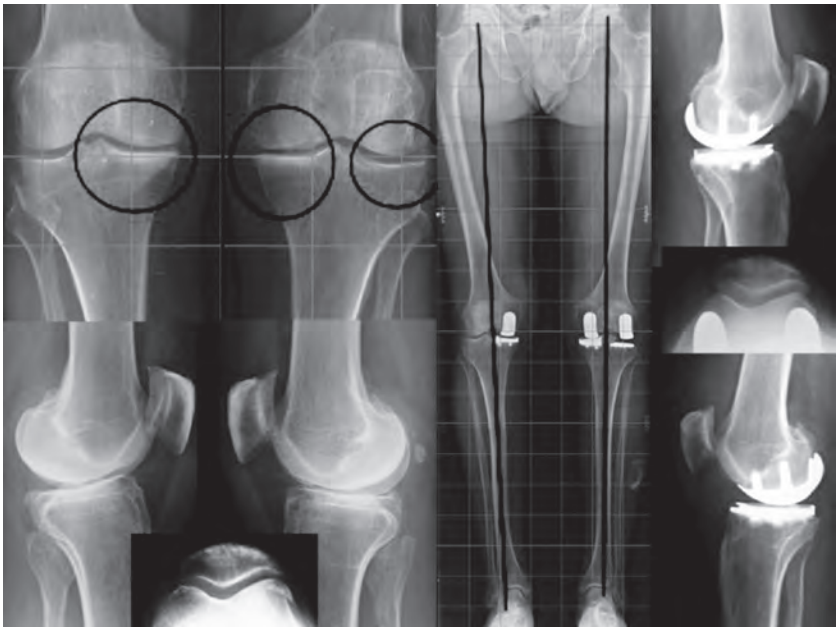

Fig. 6: 54 years old male with medial tibiofemoral OA of his right knee and medial and lateral tibiofemoral OA of his left knee. He had simultaneous bilateral medial UKR and right knee lateral UKR. The medial and the lateral side had two different tibial components for a better adaption to the anatomy of the tibial plateau.

Medial UKR is easy to convert in bi-UKR, only extending the medial mini-midvastus approach. On the contrary, performing a bi-UKR by the lateral approach done for a lateral UKR is not possible. A tibial tuberosity osteotomy is necessary to obtain adequate exposition of the medial compartment. This shrewdness should be done also when indication changes intraoperatively from lateral UKR to total knee replacement.

Surgery starts with semitendinosus and gracilis harvesting. In the last years we prefer tibialis anterioris allograft of artificial ligaments to reduce morbidity. Both the tibial and femoral tunnels are prepared arthroscopically and the graft is passed in the joint. The graft is then fixed in the femoral side, but not in the tibial one. At that time, UKR is done. After placement of the final components, the graft is fixed also on the tibial side.

CONSIDER CONCOMITANT ACL RECONSTRUCTION

In patients with medial OA and ACL deficiency, most surgeons will perform TKR. But patient younger than 55, very active and with no major deformity should be limited by this choice, with diminished proprioception and knee function. In this kind of patient, if motivated, a UKR with concomitant ACL reconstruction has to be considered (fig. 7) [17-18].

CONSIDER ALL THE AFFECTED JOINTS

In most cases a single joint causes patient's disability. Anyway, sometimes both knees, or a knee and a hip are affected. Surgeon has to evaluate the whole patient, not only his knee. If more than one joint is affected, UKR will not improve patient's function and surgery will be considered as a failure. In these cases, surgeon has to consider simultaneous replacement of all the joints affected (fig. 8).

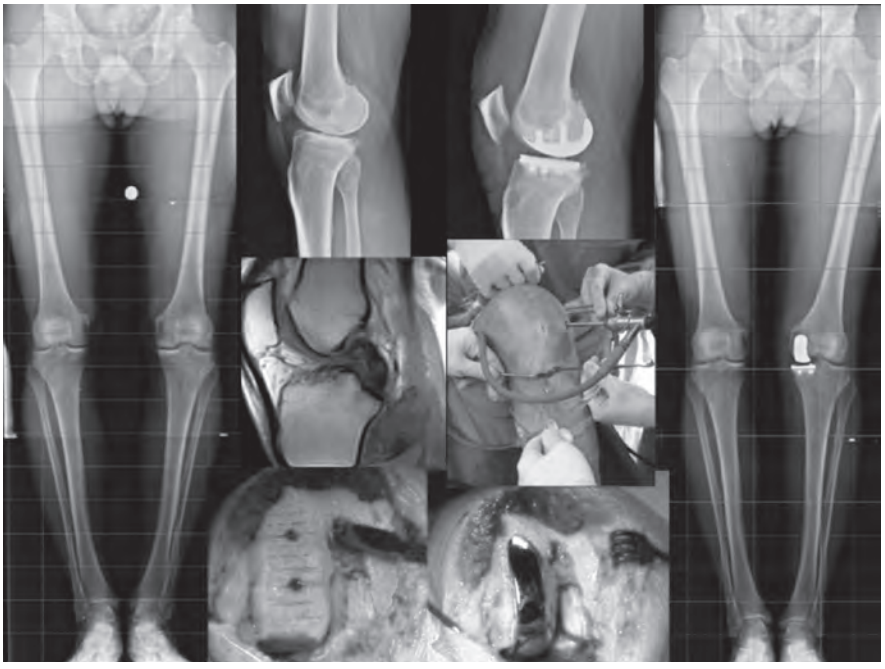

Fig. 7: 53 years-old man, very active, with right left knee medial OA and ACL insufficiency. He had successful one-stage medial UKR and concomitant ACL reconstruction.

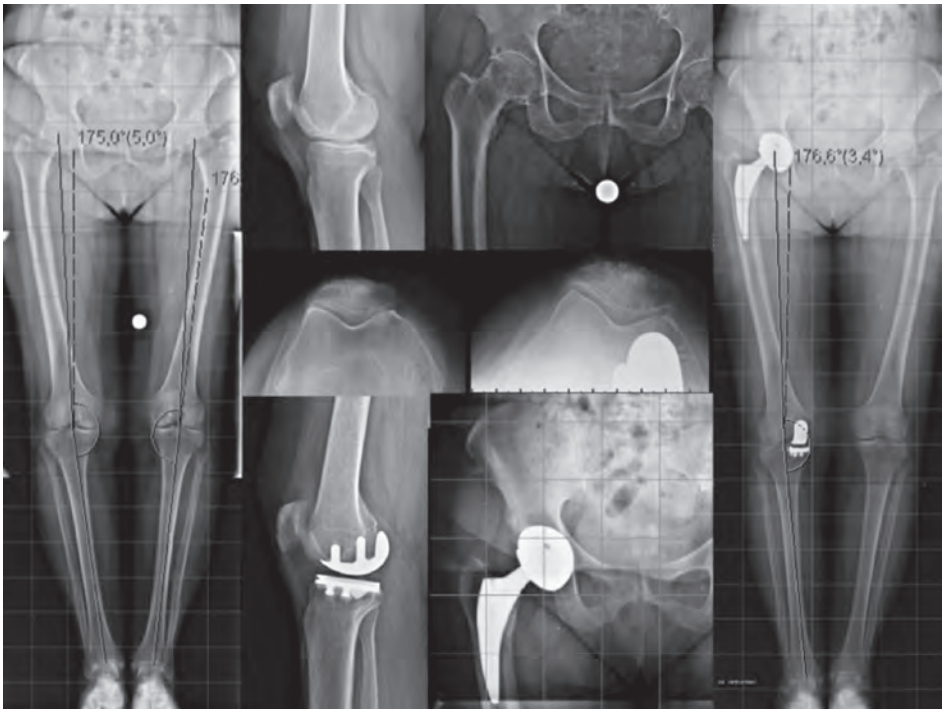

Fig. 8: 73-years old man with medial OA of his right knee and right hip OA. He had successful one-stage UKR and ipsilateral total hip replacement.

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REVISIONS OF UKA WITH TKA; MEDIAL VERSUS LATERAL UKA

C.G. MURPHY, T. AÏT SI SELMI, M. BONNIN

INTRODUCTION

Unicompartmental knee arthroplasty (UKA) provides an alternative to total knee arthroplasty (TKR) in patients with monocompartmental arthritis. The prerequisites cited in retrospective studies for a UKA, include unicompartmental disease, functioning anterior cruciate ligament (ACL), tibiofemoral angles between physiological valgus and 10° varus and no subluxation are largely accepted [17, 21], although the boundaries continue to expand.

Failure is nevertheless increasing; the inexorable consequence of increasing numbers of procedures. Conversion of the failed UKA to TKR shows favourable outcomes, but the complexity of revision surgery remains debatable, and the causes of failure different between medial and lateral unicompartmental arthroplasties. Not infrequently, papers discussing 'the failed UKA' seem to be synonymous with Medial UKA. Few studies compare the differences between the revision of these two types of prostheses to TKR. The purpose of this paper is to examine the differences between the revision of Medial and Lateral UKAs to TKR.

MEDIAL AND LATERAL UKA; NOT SYNONYMOUS

In considering revising medial and lateral prostheses, it is important to remember that they are different creatures, with different indications, biomechanics, kinematics, and for different patterns of wear.

In terms of frequency, Lateral UKAs are performed between one in ten and one in fifteen times less than medial UKAs, therefore make up less than 1% of knee prostheses implanted [58]. Indications are subtly different between medial and lateral UKA [2, 4, 42, 50], as are the diagnoses leading to unicompartmental arthroplasty. Series for either medial or lateral UKA where authors cite their respective indication are shown in Table 1. For series reporting indications for lateral UKA, primary osteoarthritis by far the most common indication, with sequalae of trauma next most common [2, 4, 39, 44, 54]. Argenson's series aside, UKA for osteonecrosis is not cited as an indication. Medial UKA indications are performed overwhelmingly for OA, with osteonecrosis (0.8% to 6%) and sequalae of trauma (0.4% to 4.5%) much less common [9, 31, 60].

Table 1: Indication for Primary UKA for exclusively medial or lateral series.

	1° OA	Osteonecrosis	Post Trauma
Lateral UKA			
Odhera 2001 44	32/38	-	-
Argenson 2008 2	24/40	21/40	12/40
Sah 2007 54	38/48	0	10/48
Ashraf 2002 4	72/88	0	3/88
Lustig 2011 39	51/54	0	3/54
Medial UKA			
Sierra 2013 60	147/175	12/175	8/175
Koskinen 2009 31	42/46	2/46	2/46
Bergeson 2013 9	825/839	7/839	4/839

Anatomical and biomechanical differences exist between the medial and lateral compartments of the knee, in particular regarding slopes; marked discrepancies of up to 27º between medial and lateral tibial slopes have been reported in cadaveric studies [25], while the Anteroposterior (AP) to Mediolateral (ML) ratio is larger for the medial side than the lateral, potentially leading to ML overhang in order to achieve AP coverage [59]. This has direct clinical relevance; an association has been shown between early UKA failure and those prostheses with a posterior tibial slope of greater than 7º [23].

Kinematics of the knee are also different between the medial and lateral compartments; femoral rollback is more pronounced laterally than medially, which may explain differing patterns in cartilage wear pre-operatively (e.g. early anterior wear for medial tibial gonarthrosis [30], posterior wear for ACL-deficient knees [64] and in polyethylene wear post-operatively [1, 54, 63].

Obviously, implants and their manufacturers have differing recommendations, with regard to femoral bone preparation, and for optimizing tibial slope; for example Accuris (Smith & Nephew Memphis TN, USA) recommend a neutral slope, while Oxford (Biomet, Warsaw IN, USA) recommend a 7° slope. Each prosthesis, medial or lateral, has specific technical challenges associated with its insertion. Surgery for lateral UKA has been described as more technically challenging than for medial joint replacement, with specific technical considerations suggested; ***i)*** to avoid excessive tibial slope, ***ii)*** to be very conservative with tibial cuts to avoid the need for excessively thick tibial components to restore alignment and stability, ***iii)*** to err toward shifting the femoral component laterally and the tibial component medially to maximize ML congruency, and ***iv)*** to carefully recess to patella from impinging against the leading edge of the femoral component [58]. Failure to adhere to the principles of appropriate patient selection, work up and technically accomplished surgery risk amplifying errors and early failure necessitating revision surgery.

Perceived difficulty of revision and technical considerations

Authors vary in their description of their perception in the challenge posed by revising a UKA to TKR. Certain authors consider revision of UKA to TKA straightforward [17, 33, 35, 57], no more complex than a TKA [28], or easier than revision of TKA [7, 34, 41]. Others are more circumspect, citing complexity of

surgery in the frequent presence of bone loss [43, 47]. Some authors are more relativistic in their descriptions; "relatively simple procedure if planned thoroughly" [57], others consider the revision of UKA to TKA "requires precision, but not is technically difficult" [13], and a procedure whose "complexity and complications compare favourably with those of TKR revision" [55]. These cases can and do present specific challenges to the surgeon.

Indications for revision for Medial UKA and Lateral UKA

Table 2 highlights the reasons for failure of UKA in the various published series. Low numbers in the studies addressing only revision of lateral UKA makes interpretation difficult, but the larger series addressing revision of both medial UKA and lateral UKA, including those from the various joint registers demonstrate that the indications for revision are broadly similar. For series that describe reasons for failure in Medial only UKAs, aseptic loosening is the number one most common indication cited in five papers [9, 52, 55, 57, 60] and progression of OA the number one in two papers [31, 43], with failure of poly insert, pain, component failure or periprosthetic fracture, and sepsis the other reasons cited. For Lateral only UKAs, progression of OA is the most commonly cited indication for revision, with aseptic loosening and component failure/ periprosthetic fracture the next most common [2, 4, 39, 44, 50, 54]. In the heterogeneous larger series, which include the joint registers, where both medial and lateral UKAs are discussed, aseptic loosening and progression of OA are cited as first and second respectively most common indications in four papers, with progression of OA and aseptic loosening respectively most common in two papers. Pain is cited as number one cause in two papers, and second most common in two more papers. Malalignment, sepsis, and poly wear make up the lesser cited reasons in each group.

RESULTS AND OUTCOMES

UKA to TKA Vs Primary TKA – are the results comparable?

Comparisons between UKA to TKA and a primary TKA are variable, and use differing yardsticks, including clinical scores, radiological data, retrospective reviews and registry data. Several authors have reported results for UKA to TKR equivalent to primary TKA [28, 35, 41, 55]. Larger series however find that the results are inferior [7, 10, 12, 27, 47, 49]. Given the high rate of usage of revision TKR prostheses (stem, augments) and presence of bone loss requiring grafts in a sizeable proportion of UKA to TKA cases (Table 3), it is reasonable to state that UKA to TKA procedures are on balance more complex than a primary TKR.

Inhomogeneous series

The nature of the publications on revision of UKA to TKA is extremely inhomogeneous. Most series are retrospective, although not all [20]. The outcomes are frequently blurred by inclusion of multiple modes of revision for the conversion of failed UKA (including polyethylene change, conversion of UKA to UKA, UKA to Bilateral UKA and UKA to PFA), differing patient cohorts (older or younger), differing prosthesis type, and for variable timeframes. However, one message seems to be emerging, especially from more recent publications; when a UKA requires revision, the best results are achieved when it is converted to TKA [22, 32, 36, 53]. Other variables in outcome include the type of prosthesis used, and in some cases, but not all [32] volume of procedures performed by the unit, with a figure of 13 cases per year suggested as a minimum "to achieve results comparable with the high-volume operators" [5]. Two are of the Nordic joint registries have previously noted the effect on volume on outcome; a

Table 2: Failed UKA; Laterality, Study size, Indications for Revision.

Author	Year	Time to Follow Up given	N°. of UKAs studied	Medial UKA	Lateral UKA	N°. of U2T	Indications for Revision	Progression of OA	Aseptic loosening	Pain	Poly wear / failure	Malalignement	Component / Peripros #	Sepsis
Lateral Only														
Argenson [2]	2008	2-23, mean 12.6	40	0	40	5	yes	4					1	
Sah [54]	2007	mean 5 years	48	0	48	0	N/A							
Pennington [50]	2006	mean 12	29	0	29	0	N/A							
Ohdera [44]	2001	mean 12.4	38	0	18	2	yes	2						
Ashraf [4]	2002	mean 9 years	88	0	88	15	yes	9	6				4	
Lustig [39]	2011	5-16 years (mean 8 years)	79	0	79	1	yes		1					
Medial & Lateral														
Lindstrand [38]	2000	mean 2 years	251	229	22	Unspecified	*Any revision	1	6	1			2	
O'Rourke 45	2005	min 21 years		122	14	17 M/2 L	??							
Pennington * <60y.o. 51	2003	mean 11years	46	44	2	1 (M/L unspec)	*Any revision			1				
Chou [14]	2012	mean 3 (1-7)	132	128	4	33 (M/L unspec)		4%	50%	21%	19%	8%		
Pearse (NZJR) [49]	2012	11 years period	236			205 (M/L unspec)		8%	36%	48%	4%			5%
Chatain [13]	2004	mean post revision 4 years	54	45	9	54 (M/L unspec)		13%	57%	9%	9%			
Hang (AJR) [22]	2010	9 years period	1035				*Any revision	17%	50%	12%				5%
Gioe (CommunityJR) [20]	2003	10 years period	516	N/A	N/A	39 (M/L unspec)	*Any revision	51%	25%		20%			

Table 2 (suite): Failed UKA; Laterality, Study size, Indications for Revision.

Author	Year	Time to Follow Up given	N°. of UKAs studied	Medial UKA	Lateral UKA	N°. of U2T	Indications for Revision	Progression of OA	Aseptic loosening	Pain	Poly wear / failure	Malalignement	Component / Peripros #	Sepsis
Author														
Koskonen (FJR) [32]	2007	18 years period	1819			234 (M/L unspec)	*Any revision	33%	44%		9%	6%	3%	
Squire 61	1999	min 15 years	140	125	15	14 (M/L unspec)	*Any revision	50%	42%					
Baker (UKWJR) [5]	2012	7 years period	1402	1331	71	Unspecified	*Any revision	4%	29%	24%				
								5% M Vs 4% M	30% M Vs 24% L	25% M Vs 21% L	5% M Vs 4% L	6% M Vs 1% L		5% M Vs 10% L
Lewold (SJR) [36]	1998	20 years	1135	995		678 M	*Any revision	26%	43%		14%			
					140	100 L		25% M Vs 4% L	45% M Vs 31% L		11% M Vs 8% L			
Saragaglia (SFHG) [56]	2013	unscecified	418	368	50	371 (M/L unspec)	*Any revision	13%	44%	4%	13%	6%	4%	
Medial Only														
Saragaglia [57]	2009	12 years period		33	0	33		4	21		7			1
Oduwole [43]	2010	5 years period	106	106	0	13		2	4	2	1			2
Saldanha [55]	2007	mean post revision 2 years	1060	36	0	36		13	14	4	4			
Pandit [48]	2011	mean 5 years (1-11)	1000	1000	0	19	*Any revision	9	1	6	6			5
Sierra [60]	2013	min post op review 2 years	175	175	0	175		59	96		7		5	5
Robb [52]	2013	mean post op review 3 years	494	24	0	24		2	12	34			1	1
Koskinen [31]	2009	mean 7 years follow up	46	46	0	6		3			3			
Bergeson [9]	2013	post op review 2 years	839	40	0	unspecified		2	15	12	2			

Table 3: Conversion of UKA to TKA; use of implants, grafts, augments.

Author	Year	U2T	Comments
Barrett [7]	1987	29	27 CR TKR, Half Stem/Augment +with screw +cement/Bone graft
Chatain [13]	2004	54	39 TKR, 14 Rev TKR including stemmed, 1 hinged.
Saldanha [55]	2007	36	6 constrained, 2 semi-constrained, 6 stems, 2 augments, 2 Bone graft
Lewold [36]	2008	778	750 TKR (655 Medial, 95 lat), 28 constrained (23 medial 5 lateral)
Oduwole [43]	2010	13	7 TKR, 6 requiring Stem/Augment/Bone graft
Pandit [48]	2011	19	17 TKR, 2 Rev TKR Stems &/Wedges
Chou [14]	2012	33	Stems 12, wedges 7
Pearse [49]	2012	205	Any revision prostheis 28%, Stems 22%, wedges 14%
Robb [52]	2013	24	Stemmed 8, Tibial augments 3, hinged 1
Sierra [60]	2013	175	PS 88, CR 81, constrained 6, Augments 53, Stems 67
Saragaglia [56]	2013	371	67% PS, 33% CR, 4% Rotating hinge. Bone Loss: F41%, T50%, Bone Graft F 31, T 112 (47% morcelised, 38% corticocancellous, 10% segmental allograft) Augments: F2, T25, Stem: 18F, 18T

U2T Number of conversions of UKA to TKA.
PS Posterostabilised
CR Cruciate retaining
F Femur
T Tibia
Rev Revision

revision rate for Oxford Unicompartmental knees that reduced from 20 to 7% if the surgeon performed more than 23 cases per year [37], while in the Norwegian registry series hospitals performing 25-50 UKAs per year had a 40% decrease in revision rate compared to those performing less than 10 procedures per year [19]. The numbers of revisions from UKA to TKA are highlighted in Table 2 under (U2Ts) where presented, and numbers range from one single revision [51] to 678 Medial UKAs to TKA [36].

Laterality and survival

One of the problems with analysis of joint register data pertaining to UKA has been a failure to consider medial and lateral implants separately, for both survival and mode of failure. Early studies report five to ten year failure rate for Lateral UKA of around 82% [4, 21, 24]. Up to ten year survival rates of 92% and 98% have been reported [2, 8, 39], and both Sah and Pennington report series with 100% survival at a mean of 5.2 and 12.4 years respectively [50, 54].

When considered together, Lateral UKA account for a low proportion of Revised UKAs [7, 13, 14, 45, 61], making interpretation of data difficult, ranging between 4% [51] to 21% [12]. Lewold et al reporting on the Swedish register were the first to stratify indication for revision by side, finding broadly similar indications for revision [36]. The study by

Baker *et al* from the UK & Wales JR was the first to assess the impact of laterality on the failure of UKA. They demonstrated that Lateral UKAs account for 6% of UKAs, that the midterm survival rates of lateral and medial UKRs are equivalent, and that the pattern of failure was similar for both medial and lateral UKAs. The only factors to influence outcome, consistent for both medial and lateral UKA were patient age and ASA status at initial surgery, with younger age and higher ASA associated with lower survival [6].

Learning Curve-experience and lessons learned

Timeline failures are another confounding factor; revision of implants inserted between 1975 and 1985 had more significant bone loss than more recent revisions, likely related to less precise earlier ancillary equipment [7, 47]. Other early failures (1984-1998) are associated with thin or oxidation-prone polyethylene bearings [15, 16, 18], or poor operative technique [38]. Early polyethylene bearing dislocations for lateral UKAs were cited by Gunther *et al.* [21], but rates were reduced following introduction of techniques to prevent dislocation.

Comparing the results of revision of UKA to TKA is difficult given the multifactorial nature of any failed prosthesis. Several authors found inferior results for conversion of UKA to TKA than for those with a primary TKA [7, 10, 12, 27, 47, 49]. Revision for pain in the absence of a clear diagnosis is not as successful as when a cause of failure has been identified [29]. Register studies by virtue of their size give more quantitative than qualitative data; Lewold's paper from the Swedish register focuses on outcome, and breaks down the indication for revision of UKA in 1135 patients, but the end point is revision for any reason, including – in addition to conversion to TKA – interventions such as exchange of either the femoral, tibial and or polyethylene components, or contralateral UKA, PFR, & mensicectomy [36].

Length of follow up

Length of follow up is extremely heterogeneous due to a combination of study design and phraseology. Joint Register studies can follow outcomes of type of prosthesis over a 20 year period [36], while others follow cohorts operated on over defined – sometimes very lengthy – periods and analyze outcomes for that timeframe [39, 61]. Others follow specific implant failure cohorts from (e.g. all UKAs performed between certain dates) for defined period post-operatively [13, 52], often with a view to measuring outcome scores at specific intervals post-operatively. Some authors specifically look at short term outcomes for a given cohort [9, 62], while others report on timeframe from initial procedures [43], others from the time of revision or failure [60]. One study reports on a series of primary UKAs performed over a 15 year period, with a mean follow up range of two years, with a mean interval between primary and revision surgery of 5 years [55]. Evidently, the reported timeframe from each study must be assessed in the context of the studies respective aim, which makes distinguishing the effect of time to revision of UKA and laterality difficult.

Implants used as a surrogate for difficulty of revision

The difficulty of assessing the technical challenge associated with revision cases for UKA to TKA has been alluded to. Another method of measuring the difficulty of revision is analyzing the type of implants, the use of bone graft, and metallic augments as a surrogate for difficulty of revision. Table 3 highlights studies that have described these features. Bone loss is common, and requires filling in 33% to 77% of revision cases [40, 46, 57]. Lack of uniformity in the description of classification of bone loss means poor comparison between studies, however the treatment options for a lack of bone stock, or for ligamentous imbalance may be inferred from the type of prosthesis used (CR, PS or Revision/Stemmed com-

ponents, or Hinged prosthesis), and the need for bone graft or metallic wedges. No studies distinguish laterality in this context.

Incision

For revision of UKA to TKA the approach used is ostensibly the same as the initial surgery. Reusing the old incision for medial UKA is uncomplicated, although a tibial tuberosity osteotomy was necessary in 3.7% of cases in the SFHG multicentre study [56], for patella baha or for excessive adherence of patellar tendon to bone. Skin problems have been reported following revision of UKA to TKA [26]. For the lateral UKA, the lateral approach can be used with a lateral arthrotomy, again with a tibial tubercle osteotomy if required – this was utilised in 12% the SFHG study [56] or using a subfascial dissection to effect a medial knee arthrotomy [40]. Although some authors have advocated mini-incisions for primary lateral UKA [2-4], there is no role for minimally invasive surgery in revision surgery.

Femur correction

In the largest study available, 90% of cases a standard femoral implant was used [57]. This is because femoral cuts for UKA are much more conservative than for TKA (5-6mm as opposed to 8-10mm respectively). Rarely is bone loss an issue. Excessive cuts on the side of the removed prosthesis must be avoided, as should avoiding excessive internal or external rotation of the cutting block for lateral or medial UKAs respectively. Accurate referencing can be achieved by placing a block the same thickness as the removed prosthesis on the posterior condyle, or even keeping the prosthesis in situ during cutting block placement; both techniques are effective for revision of both medial and lateral UKAs. Planning restoration of offset can be helped by referring to the index Operative Report, or by obtaining a lateral view of the contralateral knee. In the Saragaglia paper, although bone loss is reported in 41% cases, this "was rarely significant"; only two cases used femoral augments, and only 18 of the 371 cases used a stemmed femoral prosthesis.

Tibial correction

Bone loss is inevitably the main problem with revision of a failed UKA. A number of factors are implicated in this:

i) *Resection level:* this can be influenced by the surgeon, and by the operative technique, as well as the patient – constitutional varus, and by previous procedures. Varus deformity, regardless of its cause, will predispose to increased bone cuts (fig. 1).

ii) *Angle of resection:* in the AP plane this can be affected by excessive varus or valgus cuts, while in the lateral plane, a large tibial slope may predispose to increasingly large bony cuts (fig. 2).

iii) *Knee size:* proportionality of resection when revising UKAs is as important, if not more so, than for TKAs. Compared to a large adult male knee, further bone resection in the tibia of a female patient with a very small knee quickly leads to poorer quality bone stock and a smaller surface area. No studies have reported the size of either the implants or the polyethylene insert involved for the primary procedures or for revision procedures.

iv) *Other factors:* The presence of Granuloma (fig. 3), Cement from the previous implant, Bone Sclerosis (fig. 4), or previous surgery (HTO or ACL Reconstruction) can all lead to increased tibial resection as the surgeon seeks stable, healthy bone as a base for the tibial component, but the law of diminishing returns is very relevant here, as the biology of the bone at deeper resection levels is inferior, and may not yield the required fixation.

Bone loss should be specifically assessed pre-operatively by imaging, but intra-operative assessment under direct visualization can only be definitively confirmed following removal of implants. Minimal bone resection is key, as the quality of cancellous bone deteriorates in proportion to the depth resected. The principles remain; reconstructing bone stock while preventing mechanical failure of the newly implanted prosthesis, using bone graft (morcellised or head allograft), metallic augments, and cement or combination of all

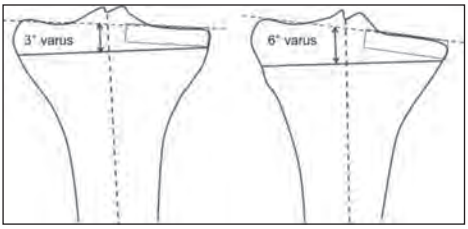

Fig. 1: Effect of varus cut on resection level.

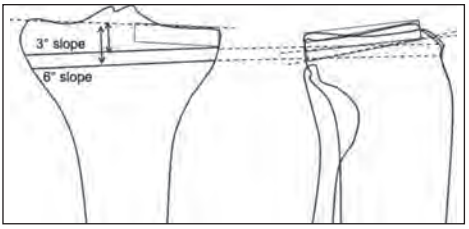

Fig. 2: Effect of angle of resection on potential bone cuts.

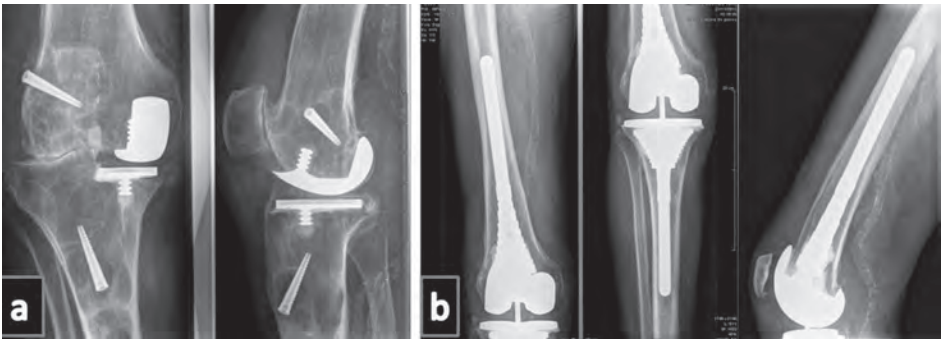

Fig. 3: Demonstrates a case of an 84yo man, presenting with severe knee pain 20 years after a medial UKA. Of note he had an ACL reconstruction using a synthetic graft 10 years prior to that intervention. Imaging showed a massive area of lysis (fig. 3a), and once an infective cause was outruled, a revision of UKA to TKR was undertaken encompassing curettage of the granuloma and insertion of a constrained long stemmed revision prosthesis (fig. 3b). Although an indirect – an unusual – cause of failure for a UKA, this case highlights the difficulty of balancing resection minimization with obtaining stable fixation.

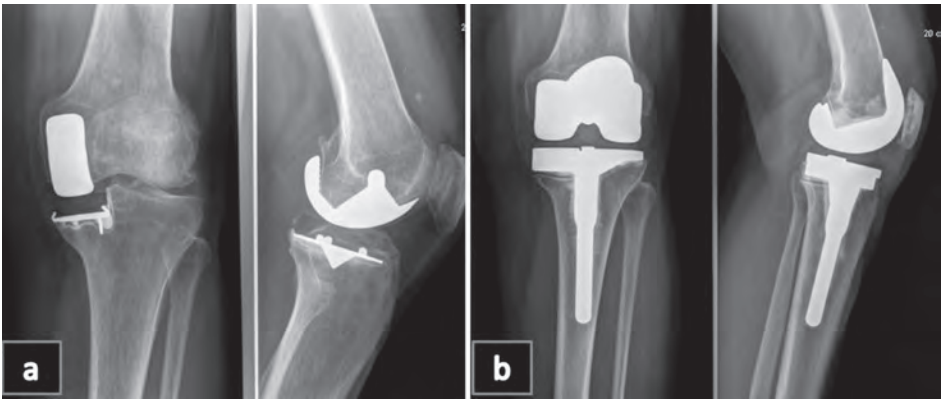

Fig. 4: Shows a clinical case of a 57 year old lady, who presented to our service two years with ongoing medial knee pain following a UKA to UKA procedure, which had been performed for persistent pain which corresponded to a site of lysis and bony sclerosis under the medial tibial plateau. Both the pain and the radiographic lysis persisted after her UKA to UKA procedure (fig. 4a), and for which she had a UKA to TKA. Although resection was as conservative as possible through the sclerotic medial tibial bone, and medial augments used with a stemmed prosthesis, and clinical symptoms have improved, the area of lysis persists at one year following her revision to TKR (fig. 4b).

three, using the implant that offers the best chance of success without excessive trade off in constraint. As seen in Table 3, what denotes a 'revision' TKR prosthesis as opposed to a 'straightforward' TKR prosthesis is poorly defined, but the use of grafts, augments and stemmed prosthesis is not uncommon for UKA to TKR procedures. The SFHG study (which reported on 426 revisions – 88% Medial UKA Vs 12% Lateral UKA) reported the use of standard TKR prostheses in only 50% of cases [56], while other authors report usage of revision type prostheses for UKA to TKR from anywhere between 11% and 85% [7, 13, 14, 43, 48, 49, 52, 55, 60].

SUMMARY

Although Medial and Lateral UKA have different indications and pathoanatomical features, revision of UKA to TKA is like any revision case; cause of failure for either Medial or Lateral UKA is frequently related to suboptimal patient selection, technical errors intra-operatively, as well as patient specific, prosthetic and mechanical factors. Intra-operative technical difficulties must be anticipated pre-operatively to plan the optimal surgical strategy. Meticulous planning of the approach must be undertaken, taking into account previous incisions. Preparation for the type of implants required is essential, including the decision between primary or revision prosthesis, the use of stemmed components, the degree of constraint required and the necessity for either autograft, allograft or metallic augments. However, avoiding excessive tibial resection is paramount, and this must be done from the primary intervention. Although there is insufficient evidence regarding the effect of laterality, revision of UKA to TKA procedures are not the same as a primary TKR, as evidenced by the escalation of bone loss and the frequent use of revision-type prostheses.

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FUNCTIONAL ASSESSMENT: SPECIFICITY OF YOUNG PATIENTS

C. DEBETTE, V. VILLA, E. SERVIEN, S. LUSTIG, O. RAYNAUD, PH. NEYRET

INTRODUCTION

In the treatment of osteoarthritis, the evaluation of patients before and after surgery is essential.

With the evolution of medicine, tribology and patient lifestyles, this evaluation has gradually extended to all aspects of patient outcomes: objective data, function, and more recently: psycho-social context, expectations, patients satisfaction, and quality of life. These data are particularly important as younger, more active and more demanding patients are now undergoing surgery for arthritis.

Just as for an older patient, a young patient expects surgery to alleviate their pain, but also to restore knee function adequatly for the resumption of professional and sporting activities. If this is not understood, the patient may be disappointed even if the objective result is satisfactory [1, 2]. As such, the quality of the result is determined by patient satisfaction.

Evaluation requires the use of scoring systems. Current scores may cover most aspects of patient assessment, but it is still often necessary to use more than one instrument. Recent scores involve the use of self-administered questionnaires to collect patient reported outcomes, thus increasing their reliability [3, 4].

CLINICAL EVALUATION AND BASIC FUNCTIONS

The oldest score is the **Hospital for Special Surgery score** (HSS) created by Insall in 1974. This evolved into the **Knee Society score** (KSS or IKS: International Knee Society score) in 1989 [5]. It is currently one of the most used score worldwide.

The KSS consists of two separate parts evaluating clinical data and knee function. The knee score and functional score are each scored out of 100 points. Objective data include alignment, range of motion, pain and stability. The functional assessment includes walking distance, stair climbing, and use of gait aids. Higher scores indicate better results. This test includes a radiographic evaluation [6].

The main advantage of this score is ease of use. It can be used before and after surgery, and applies to all stages of osteoarthritis. In addition, its psychometric properties have been validated [7].

The **Western Ontario and McMaster Universities Osteoarthritis Index** (WOMAC) is a self-administered questionnaire created in 1988 by Bellamy, and is commonly used in its shortened version [8]. It covers four domains: symptoms, stiffness, pain, and activities of

daily living. The result is a score out of 100 points, again with higher scores indicating better results.

The **Oxford score**, created by Dawson in 1998, is also widely used [9, 10]. It is a self-administered questionnaire consisting of 12 items assessing pain, walking distance, and function in activities of daily living. Twelve points is the best result and 60 points the worst.

The **Tegner Lysholm** score, published in 1985, was initially created to assess ligament pathology [11]. It is also used in the osteoarthritic knee. Out of 100 points, it includes eight items: pain, limping, use of a crutch, stability, locking, swelling, stair climbing and squats. A higher score indicates a better result.

The **Lower Extremity Functional Scale** (LEFS) is a questionnaire assessing function in daily living only and is not specific to the knee. Published in 1999 by Binkley, it contains 20 questions about standard activities [12].

These questionnaires are used to obtain an assessment of knee function in activities of daily living. That is usually sufficient for elderly, less active patients. In younger patients, however, an evaluation of knee function in sports and recreative activities, as well as an assessment of the influence on quality of life, are required.

SPORTS AND QUALITY OF LIFE

The **KOOS** (Knee Injury and Osteoarthritis Outcome Score), created by Roos in 1995, is an extension of the WOMAC intended to include an evaluation of function during leisure activities and of the repercussion of the pathology on quality of life [13, 14]. It is not a specific score for osteoarthritic but it is specific to the knee. In addition to symptoms, pain, stiffness and activities of daily living, the KOOS includes five items assessing function in sports and leisure activities (squatting, running, jumping, pivoting and kneeling) (fig. 1) and four items assessing the impact of the disease on quality of life. The calculation of this score requires standardization.

The **University of California, Los Angeles** (UCLA) score can be used to complement a classic score to evaluate sporting function [15].

Function, sports and recreational activities
The following questions concern your physical function when being active on a higher level. The questions should be answered thinking of what degree of difficulty you have experienced during the **last week** due to your knee.

	None	Mild	Moderate	Severe	Extreme
SP1. Squatting	☐	☐	☐	☐	☐
SP2. Running	☐	☐	☐	☐	☐
SP3. Jumping	☐	☐	☐	☐	☐
SP4. Twisting/pivoting on your injured knee	☐	☐	☐	☐	☐
SP5. Kneeling	☐	☐	☐	☐	☐

Fig. 1 : KOOS : sports assessment

Check one of the box best describes current activity level
1- Wholly inactive, dependent on others, and can not leave residence
2- Mostly inactive or restricted to minimum activities of daily leaving
3- Sometimes participates in mild activities, such as walking, limited housework and limited shopping
4- Regularly participates in mild activities
5- Sometimes participates in moderate activities such as swimming or could do unlimited housework or shopping
6- Regularly participates in moderated activities
7- Regularly participates in active events such as bycicling
8- Regularly participates in active events such as golf or bowling
9- Sometimes participates in impact sports such as jogging, tennis, skiing, acrobatics, ballet, heavy labor or backpacking
10- Regularly participates in impact sports

Fig. 2 : UCLA score

The patient self assigns to one of 10 categories of sporting participation, ranging from "wholly inactive, dependent on others, and can not leave residence" to "regularly participates in impact sports." (fig. 2)

The **subjective International Knee Documentation Committee (IKDC),** can be used to assess the knee of an active or athletic patient, even if it is usually used to assess the ligament pathology [16]. It is a self-administered questionnaire assessing 10 items : pain, stability, volume, blocking, and ability to perform activities of daily living and sporting activities (fig. 3).

The **Osteoarthritis of Knee Hip Quality of Life** (OAKHQOL) measures is a general score for the lower limb, and focused primarily on psychosocial assessment. It is intended to assess five domains: pain, physical activity, mental health, social support and social activities [17].

		Not difficult at all	Minimally difficult	Moderately Difficult	Extremely difficult	Unable to do
a.	Go up stairs	4❑	3❑	2❑	1❑	0❑
b.	Go down stairs	4❑	3❑	2❑	1❑	0❑
c.	Kneel on the front of your knee	4❑	3❑	2❑	1❑	0❑
d.	Squat	4❑	3❑	2❑	1❑	0❑
e.	Sit with your knee bent	4❑	3❑	2❑	1❑	0❑
f.	Rise from a chair	4❑	3❑	2❑	1❑	0❑
g.	Run straight ahead	4❑	3❑	2❑	1❑	0❑
h.	Jump and land on your involved leg	4❑	3❑	2❑	1❑	0❑
i.	Stop and start quickly	4❑	3❑	2❑	1❑	0❑

Fig. 3 : Subjective IKDC score, sporting activities section

Finally the most widely used score to evaluate impact on the quality of life is the **SF-36**, and particularly its short version, the **SF-12** [18]. This self-administered questionnaire is used in all medical specialties. In joint disease it is generally used in combination with a specific questionnaire.

It consists of two sub-scores: a "physical" score and a "mental" score. Calculation of the score is complex, however, it may be performed on-line.

NEW KSS

Patient evaluation is difficult due to diversity of age, lifestyle, sports participation and psycho-social context. Previous scores are now mostly obsolete, and it is often necessary to combine several scores, complicating the task of the surgeon.

For this reason, the Knee Society committee revised the KSS in 2012 [19-21]. This score remains the most widely used in the evaluation of patients with knee osteoarthritis. A new section called the "subjective component" was added. The knee score is now called the "objective" component. The new component is a self-administered questionnaire, which provides the reliability of patient reported outcomes. It evaluates two new areas: expectations and patient satisfaction. Function is evaluated not only in activities of daily living, but also in sports and recreational activities.

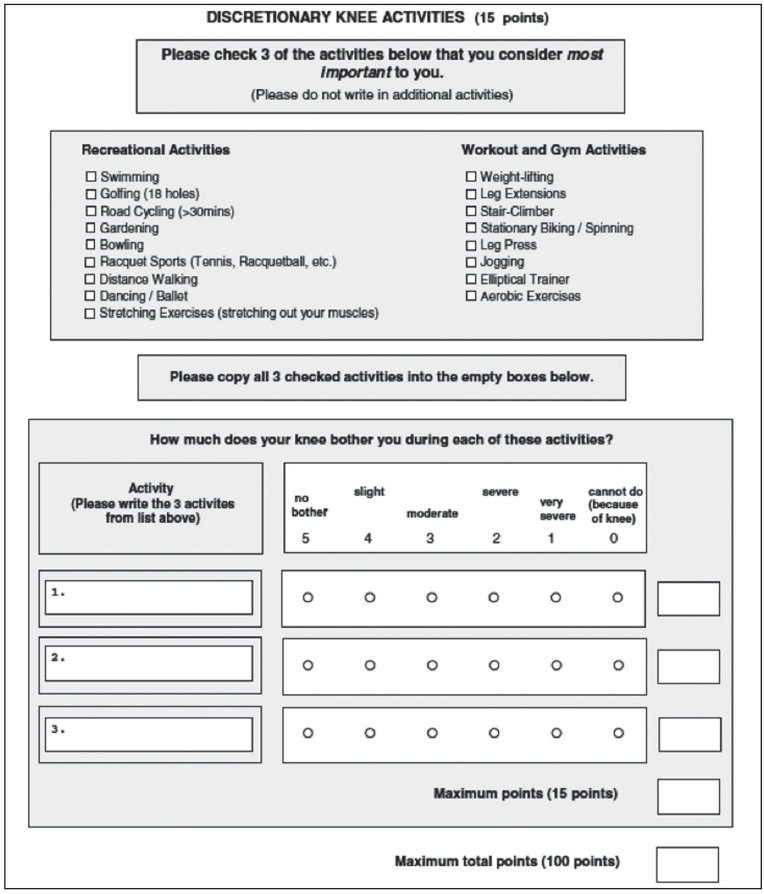

Fig. 4 : New KSS : sports assessment

There is a pre and a post operative version of the questionnaire, as the patient expectations section changes following surgical intervention. This expectation section concerns pain, activities of daily living and sports participation.

The new IKS score is more reliable, comprehensive and is suitable for young patients. It eliminates the need to combine several scores, although psycho-social aspects are still poorly evaluated. The various test scores (objective, expectations, satisfaction and function) are presented separately.

CONCLUSION

In the field of degenerative pathology of the knee, assessment tools are numerous. For the young patient, however, few scores are suitable for the evaluation of function, particularly with regard to sporting activities. This usually requires a combination of different scores. For simplicity, and in order to increase the reliability of these tests, the trend is to develop new, easy to use, self-administered questionnaires, including further assessment of sporting activity.

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TKA, UKA AND HTO IN THE SWEDISH REGISTER

A. W-DAHL, L. LIDGREN, M. SUNDBERG, O. ROBERTSSON

The Swedish Knee Arthroplasty Register (SKAR) was established in 1975 in collaboration with the Swedish Orthopedic Association (SOF) and is the oldest national arthroplasty register in the world. The orthopedic surgeons realized that it was impossible for the single surgeon, based on his own experiences, to select suitable implants and surgical techniques. The SKAR started with the purpose to gather, analyze and give feed-back on inferior techniques and implants.

Knee reconstruction surgery for OA has more than doubled in Sweden since year 2000 and is dominated by total knee arthroplasty (TKA). Uni-compartmental knee arthroplasty (UKA) and high tibial osteotomy (HTO) are dicreasing. In 2013 more than 13 000 primary knee arthroplasties were performed in Sweden with a population of about 9,5 million (SKAR 2013).

However knee reconstruction surgery in the younger patients is seen as a challenge. The challenge is not technical aspects but the life situation of younger patients with high demands on knee function, longer life expectancy and thereby an increased risk of revision. We define younger patients as those below 55 years of age. These patients have at least 10 more years before retirement, and their working life, leisure time, family and economic situation is quite different from those close to retirement or those already retired.

Since the late 90's the knee reconstruction surgery has increased substantially in patients <55 years of age. This may reflect that knee OA is an increasing among the younger or that their OA has increased in severity but also that the orthopedic surgeons nowadays are more confident to offer younger patients re-construction. Further, it may even be an effect of goverment decisions.

Around the millennium, TKA in younger patients started to increase and this has continued. The substantial increase of knee arthroplasty coincided with the time when knee arthroplasty became industrialized in Sweden by introduction of high volume units and a guarantee to patients of having surgical treatment within 3 month after being put on a waiting list. Although there was an initial increase in UKA, its use has diminished during the last years and HTO which was the most commonly used alternative for the younger patients until the millennium has decreased substantially (fig. 1). In 2013 the younger patients constituted 7% of the knee reconstruction surgery in Sweden.

The use of TKA in younger patients has increased by 8 times during the last 15 years and amounted for 6.6% of the TKA surgery in 2013.

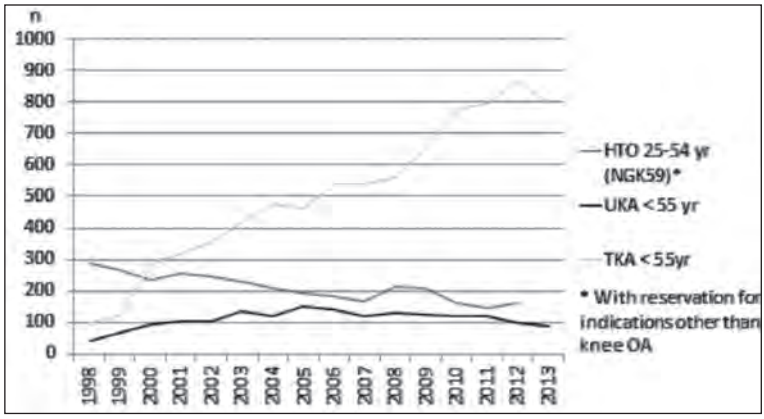

Fig. 1: High tibial osteotomy* (HTO), uni-compartmental knee arthroplasty (UKA) and total knee arthroplasty (TKA) for knee osteoarthritis in patients younger <55 years of age 1998-2013. Sources: The Swedish Knee Arthroplasty Register and the Swedish National Board of Health and Welfare.

In 2013, UKA constituted 4% of the knee arthroplasty surgery and was most commonly used in the age group of 55-64 years. About 18% of the UKA surgery was performed in patients younger than 55 years of age. 39 out of 73 hospitals performed UKA in 2013 compared to 60 out of 76 in 2007.

While TKA and UKA are used in all age groups, HTO is mostly considered in the younger and/or physically active patients. The SKAR has provided information on the knee arthroplasty surgery since 1975 while the information on HTO has been lacking.

In the beginning of the 1980s, HTO was estimated beeing 30% of the primary knee reconstruction surgery in Sweden (Tjörnstrand *et al.* 1981), decreasing to about 20% during the period 1989-1991 (Knutson *et al.* 1994). In a population based study using information from the Swedish National Board and Health's register for 1998-2007, verifying laterality and diagnosis by medical records, it was shown that the use of HTO has decreased by 30% during these years amounting for 6.8% of the primary knee reconstruction surgery in 1998, as compared to 2.5% in 2007 (W-Dahl *et al.* 2012). Similar information from the Swedish National Board of Health and Welfare, estimated HTO's to be less than 2% of the knee reconstruction surgery for knee OA in 2012.

The SKAR has shown that the revision rates in younger patients operated on by TKA and UKA increase by younger age and that the risk of revision at 10 years for TKA and UKA are doubled for patients younger than 55 years of age as compared to those 55 years and older (fig. 2) with no differences between men and woman (W-Dahl *et al.* 2010). The risk of revision for HTO increased by older age and was higher in woman than men. The risk of being converted to a knee arthroplasty at 10 years was 30% (fig. 3).

Most of the osteotomies performed during 1998-2007 were done in clinics performing less than 15 operations a year. For UKA, it has been shown that hospitals performing less than 23 UKAs a year had a 1.6 times higher revision rate than units that performed more (Robertsson *et al.* 2003). It is not unlikely that similar factors influence outcome in HTO. The use of

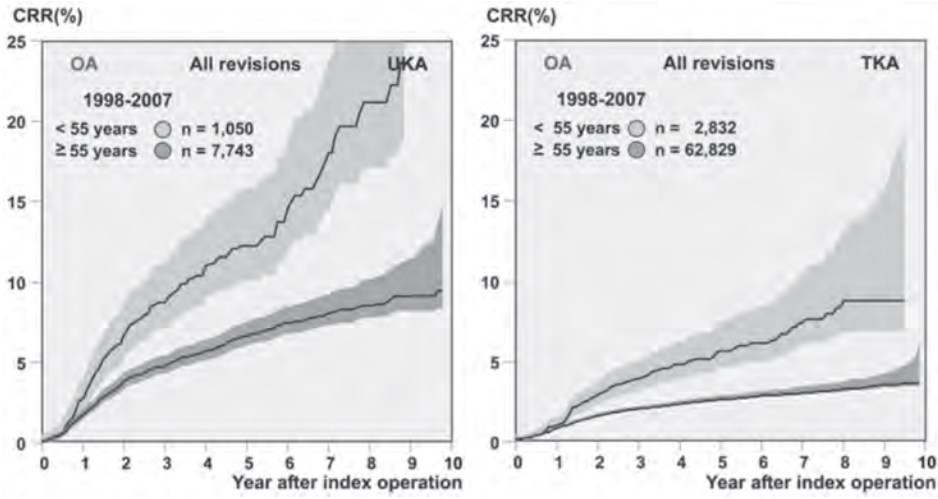

Fig. 2: The risk of revision for uni-compartmental knee arthroplasty (UKA) and total knee arthroplasty (TKA) (W-Dahl et al. 2010).

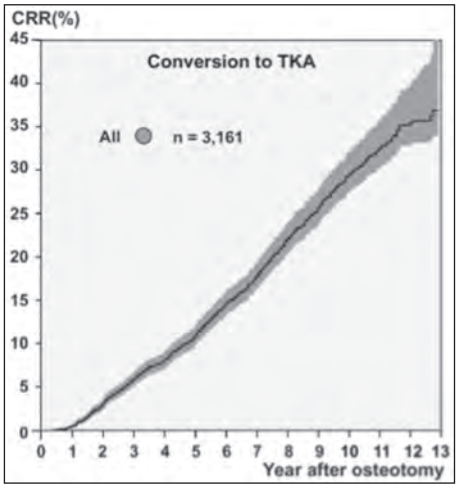

Fig. 3: Cumulative revision rate (CRR) for high tibial osteotomy (HTO) (W-Dahl et al. 2012).

HTO and UKA has diminished, with few operations spread over many hospitals and a risk of gradual loss of experience with respect to patient selection and surgical routine. In April 2013, the SKAR started registration of knee osteotomies corresponding to the registration for knee arthroplasties in order to increase the knowledge of its use, demographics, surgical methods, techniques and outcome.

As the younger patients are likely to have different demands on knee function and has a longer expected lifetime than the older patients the choice of primary knee reconstruction may be crucial. Considering their higher revision rate and the increasing use of knee arthroplasty, the burden of revision arthroplasty in Sweden is likely to increase substantially in the future.

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METAL ALLERGY IN TKA: DOES IT REALLY EXIST?

M. THOMSEN, P. THOMAS, V. KRENN

Implant-related metal hypersensitivity is a rare complication in total knee arthroplasty (Hallab *et al.* 2001; Niki *et al.* 2005; Lützner *et al.* 2013; McMaster and Patal 2013, Thomsen *et al.* 2011, Thakur *et al.* 2013). In a representative survey among members of the working group for joint replacement (AE) in Germany (86.7% response) we showed that 1,13% of patients with total knee arthroplasty (TKA) may have hypersensitivity related problems due to nickel or cobalt and that one third of them may need revision surgery (Thomsen *et al.* 2013). Thomas *et al.* (2013) had a study of 200 arthroplasty patients with complaints involving the prosthesis (130 female, 187 knee and 13 hip prostheses) and in parallel 100 symptom-free patients (75 female, 47 knee and 53 hip prostheses) were investigated.

In the knee arthroplasty patients with complaints 9.1% showed dental material intolerance, 23.5% atopy, 25.7% CMI, 18.2% metal allergies, 7.4% gentamicin allergy and 27.8% positive metal LTT (mostly to Ni). In symptom-free patients 0% showed dental material intolerance, 19.1% atopy, 12.8% CMI, 12.8% metal allergy, 0% gentamicin allergy and 17% positive metal LTT.

Although it is a rare complication in our center we see many patients with knee swelling, pain, reduced range of motion, local (fig. 1) or generalised dermatitis (Gao *et al.* 2011).

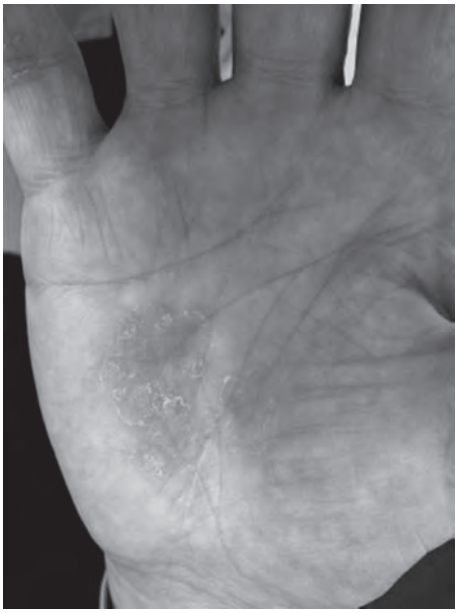

Fig. 1

In these cases we ask for the complete history, what kind of implant they have and when the problems after implantation occur.

We also need to know about hypersensitivities to metal, problems with a jeans botton or a positive epicutan test.

We recommended the clinical investigations should specifically target asymptomatic or symptomatic local swellings after total knee replacement and patients should be questioned on problems with general hypersensitivity reactions (skin rash), cardiomyopathy, and neurological changes including sensory changes, renal function impairment and thyroid dysfunction.

When the blood does show signs of infection we perform a punction of the joint.

In trouble we always perform an arthroscopy (fig. 2) to do the microbiological investigation with 5 samples for microbiologie and 5 samples (3 close to the knee components and 2 in the upper recesus) for the histological classifications which we sent to Prof. Krenn to Trier.

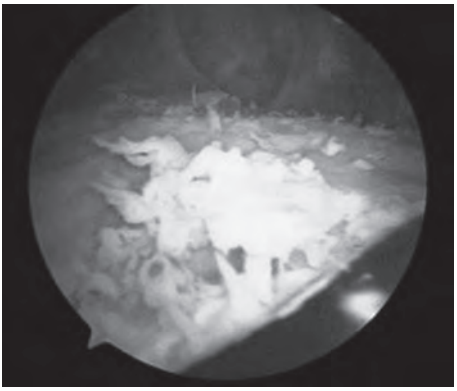

Fig. 2

Krenn *et al* (2013) said that by means of histopathology different pathogenetic synovial-like interface membrane (SLIM) patterns that lead to reduction of implant durability could be discerned, such as periprosthetic particles, bacterial infections and arthrofibrosis. Subsequently, SLIM types have been determined in a revised consensus classification including particle-induced type (*type I*) so-called non-septic loosening, infection type (*type II*) so-called septic loosening, combination type (*type III*) of bacterial and particle-induced types, indifferent type with mechanical and functional disorders (*type IV*), osseous pathologies (*type V*), arthrofibrotic type (*type VI*, endoprosthesis-associated arthrofibrosis) and allergic/immunological/toxic reactions to prosthesis material (*type VII*). Particles are characterized histopathologically according to the Krenn particle algorithm. In cases of severe lymphocyte/macrophage infiltration, necrosis, abrasion particle detection and granuloma formation, a toxic or allergic reaction to implant material should be considered.

Although hypersensitivity, allergy or metal ion overloading is a rare complication you always have to remember and before a revision a good diagnosis is important. We have seen patients with several revision operations where the problem was not seen.

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REHABILITATION OR SELF-REHABILITATION

D. BEVERLAND

In 2008 we reported on a study looking at post-operative rehabilitation [1]. The aim of this study was to investigate whether a standard course of outpatient physiotherapy improves the range of knee motion after primary total knee arthroplasty. One hundred and fifty patients were randomly assigned into one of 2 groups. One group received outpatient physiotherapy for 6 weeks (*group A*). Another received no outpatient physiotherapy (*groupB*). Range of knee motion was measured preoperatively and at 1-year review. Validated knee scores and an SF-12 health questionnaire were also recorded.

There was no statistical difference in range of motion between the two groups at one year. No difference either was noted in any of the outcome measures used. For example outpatient physiotherapy did not improve the ability to walk further nor did it decrease the necessity for walking aids.

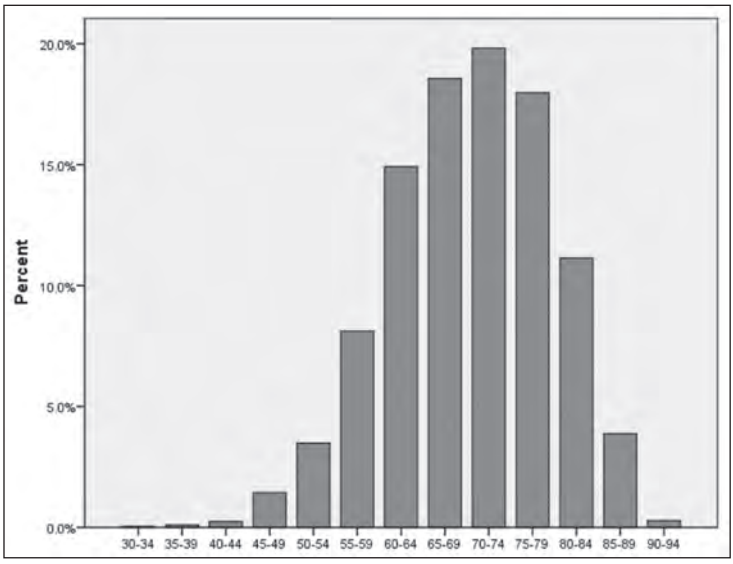

Fig. Age Group Primary Knees - Age breakdown of my last 5,000 knee arthroplasties

The economic gains of not having to undergo outpatient physiotherapy are considerable particularly in transport and staffing costs.

As can be seen from the figures below our population are generally within the age limits of retirement. It is possible that in younger patients outpatient physiotherapy could affect the speed of return to work and the duration of sickness payments although this would have to be offset against the cost of attending physiotherapy.

In conclusion, in our population outpatient physiotherapy did not improve the range of knee motion or other outcome measures at one year after primary total knee arthroplasty and therefore at present "self-rehabilitation" does not seem unreasonable.

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WHAT I DO IN MY CLINICAL PRACTICE

D. BEVERLAND

PREOPERATIVE EDUCATION OF PATIENTS

Each patient receives an 18 page document that outlines what they can expect when they have their knee replaced. The document goes over all the complications that can happen ranging in severity from constipation to death. For the more common complications we give the frequency of each in our last 1000 cases.

From my perspective the key thing is to ensure that the patient's expectations are reasonable. The important message that we give out is that one year from surgery one in every 20 patients will say that their knee is perfect, one will say that their knee pain is as bad or worse than before surgery and the other 18 have some degree of pain but less than before surgery.

DVT PROPHYLAXIS

Each patient is individually risk assessed for VTE and a typed record of this assessment is made in the notes. Patients with a personal history of DVT or PE or any patient receiving active treatment for cancer receives Exoxaparin (low molecular weight Heparin daily for 28 days commencing 6 hours or more after surgery. The normal dose is 40mg daily except in patients who weigh 100Kgs or more in which case the daily dose is 60mg. Normally this is self-administered by the patient following discharge from hospital. Patients on Warfarin pre-operatively receive bridging Exoxaparin at the time of surgery.

All other patients, who make up the significant majority, receive Aspirin 150mg daily for 6 weeks [1]. This commences again 6 hours following surgery. Patients who are taking Aspirin pre-operatively stop taking it a week before the operation unless they have a history of TIA or CVA in which case they keep taking it.

TOURNIQUET

I routinely use a tourniquet. This is inflated after 5 seconds of elevation and immediately before the skin incision. I close the wound with the knee flexed to 90 degrees and the tourniquet is deflated as soon as wound closure commences. In a routine case tourniquet time is about 30 minutes.

If there are concerns about peripheral vascular disease or if there is calcification visible in the arterial tree of the lower limb then I do not use a tourniquet.

DRAIN

I last used a drain in a primary knee in 1994. I believe that the only action that a wound drain has is to increase the blood loss.

ANAESTHESIC LOCAL INJECTIONS

We now try to avoid both femoral and sciatic nerve blocks:

- ➢ We use 200mls of Ropivacaine hydrochloride 2mg/mL.
- ➢ Immediately prior to implantation of components we inject the posterior capsule with 5 eparate aliquots of 10mls each with the knee flexed to greater than 90 degrees. Care is taken to avoid an intra-arterial injection.
- ➢ Then 5ml subperiosteally into of the medial and lateral edges of the femoral condyles.
- ➢ Then after implanting the components and closing the deep fascial layer 40ml are injected into each side of the wound.
- ➢ Then 30ml are injected directly into the joint.
- ➢ And the remaining 30ml is injected percutaneously directly onto the femur just above the wound.

POST-OPERATIVE KNEE FLEXION

At the end of the operation we place the knee in a flexion jig at 90 degrees for 6 hours. We have shown that this results in a modest but significant decrease in blood loss [2]. However the jig must not be left on for more than 6 hours.

POST-OPERATIVE PAIN MANAGEMENT

1 gram of IV paracetamol 6 hourly for the first 24 hours. This is in combination with non-opiate oral analgesia. An oral opioid is prescribed for breakthrough pain. We try to avoid parenteral opiates.

REHAB

When possible we mobilise fully weight bearing on the day of surgery if not then on the day following surgery. This first mobilisation is normally done by a physiotherapist. We have physiotherapy cover 7 days per week. Patients are encouraged to walk to the dining room for their meals on the first post-operative day. When the patient has successfully completed stair practice with the physiotherapist they can go home. By the end of the third post-operative day 76% of our patients have been discharged to either their own home or that of a relative.

We do not use CPM and once the patient leaves hospital they do not receive any further physiotherapy [3].

LITERATURE

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POSTOPERATIVE MANAGEMENT AFTER TOTAL KNEE ARTHROPLASTY IN SCOTLAND: La méthode Caledonian™

F. PICARD, A. KINNINMONTH, D. McDONALD

INTRODUCTION

Le Golden Jubilee National Hospital (GJNH) est un hôpital national Ecossais situé à Glasgow au bord de la Clyde River. Cet hôpital du NHS *(National Health Service)* est entré en service en 2002 pour devenir l'un des principaux centres de chirurgie orthopédique et cardiologique d'Ecosse et de Grande-Bretagne. Presque le tiers de toutes les prothèses Ecossaises sont opérées au GJNH ce qui représente plus de 3000 arthroplasties par an. Cet hôpital est l'un des plus gros centres d'arthroplastie de Grande-Bretagne.

Il s'agit d'un hôpital national qui reçoit des patients venant de toute l'Écosse, ce qui représente un territoire très étendu avec une superficie de plus de 78.000 km^2 (presque la moitié de la Grande-Bretagne) et constitué de multiples territoires dont des îles qui ne sont desservies que par bateau ou par avion. La première difficulté pour ce type de prise en charge est d'organiser la visite préopératoire appropriée pour des patients qui sont parfois, dans des conditions médicales et orthopédiques, peu propices à de longs voyages allez/retour entre leur lieu d'habitation et l'hôpital. La deuxième difficulté est d'offrir des conditions idéales pour un suivi rigoureux et efficace de ces patients. La prise en charge de tous les patients y compris ceux habitant à des endroits très reculés du centre chirurgical nécessite une logistique adaptée sans compromettre la qualité ni du traitement ni du suivi postopératoire.

Nous voudrions, dans cet article, rapporter les détails de la prise en charge de ces patients depuis leurs examens préopératoires en passant par leur hospitalisation et les soins qui sont prodigués pour finir par l'organisation des soins postopératoires et le suivi de ces patients au GJNH. Ce "parcours" de soin (**patient's pathway)** sera détaillé et nous insisterons plus particulièrement sur la méthode de prise en charge de la douleur postopératoire appelée méthode calédonienne) "Caledonian" (de Calédonie ancien nom picte de l'Ecosse) et qui signifie **"Clinical Attitudes Leading to Early Discharge"**.

De manière à rendre cet exposé plus "digeste" et afin d'illustrer le parcours de ces patients, nous présenterons et suivrons le cas d'une patiente venue des Iles Shetland pour bénéficier de la pose d'une prothèse. Par ailleurs, nous appuierons cette démarche par nos résultats d'audit et de recherche rapportés ou publiés dans la littérature.

LE PARCOURS DU PATIENT

La visite préopératoire est un moment décisif de la prise en charge du patient. C'est au cours de cette période que le programme pré, per et post-chirurgical sera expliqué et défini de même que l'indication chirurgicale la plus adéquate au problème du patient. Trois catégories de patients sont adressées et donc reçues à cette visite préopératoire :

- *La première catégorie* est constituée des patients qui ont déjà été vus par les chirurgiens orthopédistes dans un autre établissement et pour qui l'indication de prothèse de genou a été posée. *Il s'agit du cas de Madame W. que nous allons suivre dans cet article. Lorsque nous évoquerons cette dame le texte sera en italique*.
- *La deuxième catégorie* est constituée des patients qui sont adressés directement par un chirurgien pour avis spécialisé. Il s'agit souvent de problèmes compliqués de type ostéotomie, de prothèses complexes de première intention, ou de complications sur prothèses existantes.
- *La troisième catégorie* est constituée de patients qui sont adressés directement par les médecins généralistes dans le cadre d'une consultation habituelle appelée **"See and Treat"**. Ces patients vont donc être vus pour la première fois par un chirurgien orthopédiste du service qui établira un diagnostic et offrira une conduite thérapeutique qui pourra être chirurgicale si nécessaire. Ces patients seront soit réorientés vers d'autres collègues si le traitement chirurgical n'est pas nécessaire ou bien seront revus pour une consultation préopératoire ultérieure. Dans le cas de patients venus de loin et dont l'indication opératoire est indiscutable, des aménagements horaires sont réservés pour qu'ils soient vus le même jour. Dans ce cas, la procédure est la même que celle de la première catégorie.

Nous nous intéresserons dans cet article à la première catégorie de patients c'est-à-dire ceux adressés par des collègues orthopédistes pour prothèses totales ou uni-compartimentales (ou prothèse de hanche).

La visite préopératoire : ou comment préparer le postopératoire ?

Les patients sont reçus tout d'abord en consultation par une infirmière spécialisée dans le **"preassessment"**. Cette personne va sélectionner, dans le dossier du patient, toutes les informations nécessaires à une évaluation médicale et chirurgicale adéquate. Le dossier du patient est en fait constitué de tous les documents compilés par la NHS depuis l'ouverture du dossier de ce patient ! Il s'agit parfois de millier de pages ! L'infirmière va regrouper les informations pertinentes du dossier médical, mais aussi des derniers courriers des chirurgiens orthopédistes référant le patient pour une indication définie. Une feuille de synthèse est établie par ces infirmier(e)s pour faciliter la consultation des autres intervenants. Ces documents, d'une vingtaine de pages, vont circuler entre les mains de tous ceux qui vont être impliqués dans le traitement ou la prise en charge du patient (fig. 1).

Fig. 1 : Visite préopératoire. Les patients sont revus par chaque intervenant. Les radiographies de même que certains documents sont consultables par internet.

Un interne va ensuite voir le patient afin de vérifier que toutes les informations ont été enregistrées et va vérifier que toutes les radiographies adaptées à la pathologie ont été prises ; si tel n'est pas le cas le patient sera envoyé en radiographies afin de prendre des clichés adaptés au problème. Pendant les périodes où le patient est libre entre les consultations, il remplit les fiches des scores fonctionnels (Oxford,

SF12 et SQL) et remplira les premières pages du livret de traitement qui suivra le patient tout au long de son parcours. Ce fascicule contient un DVD des exercices à faire avant et après chirurgie depuis la sortie jusqu'à la consultation de contrôle (six semaines pour les genoux et 12 pour les hanches).

Si il n'y a pas de doute sur l'indication chirurgicale, le patient sera vu par un des médecins qui débute la batterie des examens : ECG, bilan sanguin, bilan urinaire, des prélèvements au niveau des aisselles, de l'aine et du nez à la recherche de staphylocoques résistants à la Meticiline ainsi qu'électrocardiogramme, voire échocardiographie si nécessaire.

Dans le cas de patients présentant des problèmes médicaux importants (et cela est très fréquent dans nos consultations avec ASA moyen entre 2 et 3 dans la majorité des cas), un anesthésiste va voir le patient dans la foulée, sinon le patient est vu par un PA (**Physician Assistant**).

*Dans le cas de madame W., l'ensemble des examens médicaux et de l'évaluation médicale préopératoire a été effectué par une équipe de l'hôpital où est rattachée la patiente (pour cette dame, c'est l'hôpital des Shetland). Une fois l'ensemble des documents dûment remplis par le patient, les résultats ont été envoyés dans notre service et revus par une infirmière du service de consultation qui a demandé des informations supplémentaires. L'anesthésiste a également revu le dossier afin d'anticiper un quelconque souci, de même que le chirurgien qui a pu avoir accès aux radiographies grâce au système PACS couvrant le territoire national. Comme tout était en règle, la patiente a voyagé en avion pour rejoindre l'hôtel de l'hôpital où elle a séjourné un jour (plus si besoin) avant l'intervention. Cette dame a donc été prise en charge par l'équipe de "**preassessment**" qui a confirmé que tous les examens étaient en ordre avant l'opération qui a lieu le lendemain de son arrivée.*

Une fois que le patient a été vu par l'ensemble de l'équipe, le chirurgien orthopédiste va voir le patient, le réexaminer, confirmer (ou non !) le diagnostic et l'indication chirurgicale et demander le matériel nécessaire à la chirurgie. *Aucun matériel supplémentaire n'était nécessaire pour cette dame, mais si tel avait été le cas, cela aurait été fait avant cette consultation*.

La prise en charge du suivi postopératoire va donc débuter à ce moment. En effet, il est capital de comprendre qu'à partir du moment où l'indication chirurgicale a été posée, la réussite du traitement chirurgical et surtout son résultat à long terme va dépendre bien évidemment du geste chirurgical, mais surtout de la qualité de la prise en charge après l'opération.

Deux groupes de thérapeutes vont intervenir à ce moment du parcours : les kinésithérapeutes et les ergothérapeutes. Tout d'abord les kinésithérapeutes vont évaluer le handicap physique et apprécier les besoins pré et surtout postopératoires du patient. Ils apprécient les déficiences musculaires ou la présence de maladies chroniques comme une maladie rhumatismale. Ils vont déterminer les mesures à prendre pendant l'hospitalisation et surtout après l'hospitalisation en ce qui concerne la rééducation. Par exemple, une patiente de 70 ans atteinte de polyarthrite rhumatoïde venant pour une seconde prothèse de genou et ayant une faible mobilité utilisant des cannes spéciales ou un "**trolley**" nécessitera une prise en charge soit dans un établissement hospitalier proche de son domicile ou une prise en charge adaptée par un kinésithérapeute à domicile. Cette évaluation faite en préopératoire va permettre une mise en place de ce programme en amont de la sortie du patient. Les kinésithérapeutes font ce que l'on appelle une "**knee class**" où tous les patients présents à la consultation du matin (il y a un autre groupe l'après-midi) assistent à une présentation qui explique toutes les étapes que les patients vont traverser. Habituellement, un kinésithérapeute projette des diapos qui montrent les détails des exercices kinésithérapiques. Pendant cette réunion, les patients sont bien sûr libres de poser toutes les questions qu'ils souhaitent et peuvent à tout moment interroger n'importe quel membre de l'équipe afin de comprendre leur prise en charge.

Des ergothérapeutes vont évaluer, eux aussi, le patient et ses capacités en fonction de son envi-

ronnement. Cette évaluation est primordiale et permet d'apprécier au plus juste les mesures nécessaires à prendre avant l'opération de façon à renvoyer le patient à son domicile dans les meilleures conditions dès que possible après l'intervention chirurgicale. Par exemple, pendant cette consultation seront évalués les sanitaires, les douches au domicile du patient ou la présence de tapis au sol. Ces facteurs seront discutés avec le patient et les services sociaux locaux dans le but d'améliorer l'environnement du patient pour limiter les risques de chute ou de luxation dans le cas des PTH.

Madame W. a été revue par l'équipe et ne nécessitait pas de mesures particulières.

Ces informations sont transmises aux services qui gèrent les entrées et les sorties des patients afin d'organiser la date chirurgicale en fonction des besoins. Après une consultation qui a duré plus d'une demi-journée, le patient va quitter la consultation et reçoit son rendez-vous opératoire.

Madame W. rejoint le service d'hospitalisation.

A la fin, le patient très largement informé par l'ensemble de l'équipe va signer un consentement éclairé sur lequel sera indiqué le type et le côté de l'intervention chirurgicale ainsi que les complications potentielles de l'opération.

Cette phase préparatoire est capitale car c'est à ce moment-là que le patient sait exactement de quel type d'intervention chirurgicale il va bénéficier, comment vont se dérouler toutes les étapes, combien de temps il restera hospitalisé et comment se fera le suivi opératoire. Il sera informé sur l'organisation de ces visites obligatoires à six semaines, à un an, à cinq ans et à dix ans. Toute l'équipe aura insisté sur deux points essentiels : **le patient devra être actif durant son traitement et l'hospitalisation sera de courte durée**.

Madame W. sera suivi par téléconférence.

L'admission : ou comment confirmer des modalités de sortie et le postopératoire ?

L'hospitalisation se produit la veille ou le jour de l'opération chirurgicale. Le patient est reçu par les infirmières et le médecin de service. Puis c'est le "défilé des intervenants" : l'anesthésiste, le kinésithérapeute, l'ergothérapeute et le/les chirurgiens. Tous vont insister de nouveau sur la prise en charge postopératoire immédiate et reformulent très clairement au patient qu'il sera debout très précocement le jour de l'opération si possible, qu'il recevra l'assistance de l'équipe, mais qu'il devra être indépendant et actif le plus rapidement possible. Enfin, on confirmera le plan de sortie de ce patient. Les données médicales, chirurgicales, le consentement éclairé relu et déjà signé par le chirurgien et par le patient seront vérifiés, et le patient sera marqué avec un feutre indélébile sur le côté de l'opération.

L'opération chirurgicale n'est pas le sujet de notre propos. Cependant, il y a plusieurs faits importants à décrire et qui vont conditionner les soins postopératoires et la gestion des douleurs postopératoires :

- Chaque patient va recevoir 300 à 600 mg de Gabapentin (Neurontin), 30 mg de Temazepam, 150 mg de Ranitidine 2 heures avant l'opération.
- Le garrot pneumatique est utilisé dans la plupart des interventions de prothèses du genou de même que la navigation ce qui permet d'enregistrer toutes les informations obtenues pendant l'opération.
- Chaque patient bénéficie d'une rachianesthésie utilisant une infusion de Propofol. A la fin de l'intervention, le patient reçoit une anesthésie locale appelée "CALEDONIAN technique" qui est basée sur les principes de Kerr et Kohlen [1]. La technique consiste à injecter 200 ml de Naropin (Ropivacaine) à 0.2 % au total qui sont réparties de la façon suivante : une injection de 50 ml dans les capsules postérieures et l'échancrure fémorale, 30 ml

au-dessus dans l'espace supra patellaire au contact de l'os, quelques millilitres dans les plans collatéraux périphériques et autour du tendon rotulien et la tubérosité tibiale, et enfin la mise en place d'un cathéter pour l'injection du produit anesthésique avant la fermeture du genou [2]. Finalement 100 ml de produits sont injectés dans les tissus sous-cutanés et 20 ml seront injectés dans le cathéter après fermeture de deux plans sous-cutanés et cutanés. Le cathéter va rester en place pendant 24 heures et quelquefois 48 heures dans le cas des prothèses de révision. Une pompe de type Elastomeric contenant 270 ml de Ropivacaïne diffusant à un débit de 10 ml par heure sera fixée au bloc opératoire et le patient mettra cette pompe dans sa poche (fig. 2). Aucun redon n'est mis en place ou exceptionnellement. Il convient d'ajouter que nous utilisons pour tous les patients l'acide Tranexamic à la dose fixe de 2.5 g préopératoire ainsi qu'une antibioprophylaxie à la Gentamicine et la flucloxaciline. Un pansement collé de type hydrocolloïde (Duoderm avec Acquacel) occlut l'incision. Ce type de pansement est important car il va permettre au patient d'être mobilisé immédiatement sans risquer d'engendrer de phlyctènes ni empêcher la flexion du genou. Ce pansement permet aussi de se doucher [3].

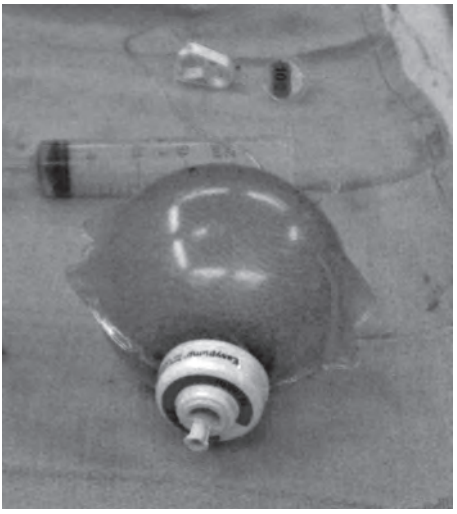

Fig. 2 : Pompe élastomérique contenant 270 ml de Naropine 0.2 % fixe à un cathéter intra-articulaire que le patient conservera au moins 24 heures.

Prise en charge postopératoire

Un bandage compressif sera laissé en place pendant 24 heures parfois moins longtemps et est remplacé par un système de type "**Cryocuff**" couvrant le genou. A la sortie du bloc opératoire, le patient sera orienté dans le département de post-anesthésie où il sera équipé de bas à varices et de bottes à impulsion alternée qui seront conservées jusqu'à sa sortie de l'hôpital. Le patient n'ayant pas eu d'anesthésie générale, mais une rachianesthésie sera reconduite rapidement dans sa chambre. A son retour dans le service, les kinésithérapeutes vont venir contrôler la disparition de l'effet de la rachianesthésie (faiblesse musculaire et le degré de paresthésie). Le patient a une voie d'abord veineuse mais pas de perfusion ce qui le libère de "toutes sortes de tubes" limitant sa mobilisation.

Le protocole d'anticoagulation a été pendant très longtemps stratifié en phase préopératoire et les patients qui n'avaient pas d'autres risques que l'intervention chirurgicale recevaient de l'aspirine 150 mg. Les autres BMI>40 et facteurs médicaux recommandant des anticoagulants de type HBPM (comme par exemple une histoire familiale de thromboses) étaient mis sous injection quotidienne d'HBPM. Les patients, au passé d'embolie pulmonaire ou phlébites confirmée, étaient mis sous AVK.

Malheureusement, notre établissement nous a imposé les consignes du SIGN et NICE guidelines, de sorte que tous les patients reçoivent HBPM ou anticoagulants oraux que nous avons arrêtés très vite du fait des complications [4]. Un audit dans le département n'a pas confirmé la supériorité de ce protocole et nous sommes en passe de revenir au protocole précédent.

Mais la technique de récupération fonctionnelle accélérée ne concerne pas que l'anesthésie locorégionale que nous venons de décrire mais aussi l'approche multidisciplinaire.

Madame W. a bénéficié du plan habituel.

Les infirmiers reçoivent les patients qui reviennent du bloc opératoire ou de la salle de surveillance postopératoire.

Madame W. est bien sûr parfaitement éveillée avec une voie d'abord veineuse mais pas de perfusion, ni cathéter urinaire, ni drain. Les seuls éléments qui retiennent la patiente à son lit sont les bottes à pression alternée qu'elle conservera depuis le premier soir et chaque nuit jusqu'au départ. Le premier lever se fait dès que les effets de la rachi-anesthésie ont disparu. L'infirmière avec l'aide d'un kinésithérapeute contrôlera tension artérielle et saturation en oxygène.

Les kinésithérapeutes et ergothérapeutes entrent en action les premiers jours. Les kinés commencent immédiatement le programme de récupération fonctionnelle. Le patient est levé le plus tôt possible, voire même habillé quelques fois et marche avec un appareillage de type Zimmer. Le kiné s'occupe de la mobilisation, des transferts et des exercices. Les ergothérapeutes prennent en charge tous les aspects fonctionnels liés à l'environnement du patient ; par exemple, tout ce qui doit être fait pour éviter une luxation pour les hanches !

La douleur postopératoire est prise en charge par "l'équipe de la douleur" comprenant médecin et infirmiers qui revoient systématiquement chaque patient. Un protocole standardisé comprend 1 comprimé d'Oxycontin toutes les 6 heures. Une pompe à diffusion continue infuse les anesthésiants pendant 24 heures dans le genou du patient. D'autres médicaments tels que des anti-inflammatoires sont parfois donnés, toujours sous couvert de protecteurs gastriques. Puis l'équipe de la douleur va adapter à chaque patient le traitement qui leur convient de même que le traitement de sortie qui est organisé avec le pharmacien associant produits morphiniques ou antalgiques standards et anti-inflammatoires.

Madame W. est levée le premier jour comme presque 50 % des patients et se déplace avec un cadre de Zimmer pour aller aux toilettes. La patiente dînera sur un fauteuil qui se trouve dans sa chambre et sera aidée pour être recouchée [5] (fig. 3).

Fig. 3 : Premier lever quelques heures après la chirurgie.

Quelques patients ont besoin de plus d'antalgiques de type "**morphine patch**", voire même une péridurale de secours, heureusement rare. De plus, il est parfois nécessaire d'adjoindre des antiémétiques pour contrecarrer l'effet de ces morphiniques.

Après une nuit généralement calme car la pompe et les antalgiques font leurs effets, le kiné. vient pour lever les patients. Puis l'ergothérapeute alors intervient pour aider le patient à s'habiller. Le pansement est contrôlé et n'est changé que s'il y a présence anormale de sang ou autre fluide. Sinon, le pansement restera en place pour au moins 5 jours et ne sera remplacé que par les services infirmiers locaux du patient ou le cabinet médical dont le patient dépend. Les pansements au niveau de genou sont plus souvent changés que ceux de la hanche. Cependant, parce que nous utilisons un pansement hydrocolloïde et adhésive flexible, il est beaucoup moins nécessaire de les changer en comparaison des pansements de type Mepore [6]

La sortie

Les kinésithérapeutes et ergothérapeutes estiment que le patient peut quitter le service lorsque les transferts du lit au fauteuil, à la douche sont faciles, qu'ils peuvent prendre leur douche

et faire les exercices par eux-mêmes, monter et descendre les escaliers seuls et gérer facilement leur environnement tels que leur cuisine, leur chambre, les couloirs… (fig. 4).

Fig. 4 : Le lendemain de l'intervention ; le patient est debout habillé et déambule avec un cadre de Zimmer ou des cannes.

La patiente était prête à sortir de l'hôpital au soir du troisième jour. Elle restera un jour supplémentaire car elle reprendra l'avion le lendemain. La durée du vol est d'une heure et trente minutes (fig. 5).

Les critères de sortie sont définis et standardisés. Chaque membre de l'équipe médicochirurgicale : infirmière soignante, anesthésiste, médecin du service, équipe de la douleur, kinésithérapeute, ergothérapeute, personnel du service d'arthroplastie, pharmacien et… le chirurgien vont cocher des cases concernant le statut du patient sur un tableau accroché sur un mur de sa chambre. Tout le monde peut consulter ce tableau à tout moment.

Fig. 5 : Retour en avion après 4 jours

Les patients reçoivent un numéro de téléphone qui peut être appelé à tout moment en cas de problème. Ils seront revus à 6 semaines (pour les genoux et 12 pour les hanches).

Le suivi

Le patient recevra un ou plusieurs coups de téléphone (si nécessaire) de la part des services d'arthroplastie. Ce service est constitué de kinésithérapeute et d'infirmiers spécialisés en arthroplastie qui savent identifier les signes cliniques, fonctionnels et même radiographiques douteux. En cas de doute, le personnel transmet l'information à l'interne, voire le chirurgien de garde.

Madame W. a été contactée à 10 jours. Le pansement a été changé une fois sans souci. Il n'a pas été nécessaire d'enlever les fils qui sont ré-

sorbables. La patiente n'a pas été envoyée auprès d'un kinésithérapeute et suivra "au jour le jour" les consignes données dans le fascicule. La douleur est par ailleurs bien contrôlée avec le traitement d'appoint. Le suivi est effectué par téléconférence (fig. 6).

Fig. 6 : Retour au domicile !

Les autres patients reviendront à six semaines date à laquelle ils seront revus par le service d'arthroplastie. Une radiographie sera prise et s'il y a le moindre problème, le patient sera revu d'abord par un interne, puis par le chirurgien responsable du jour et enfin le ou les chirurgiens ayant effectué l'intervention chirurgicale.

Toutes les radiographies des patients revus dans la journée seront distribuées à un ou plusieurs chirurgiens au hasard dans le département qui va/vont revoir toutes les radiographies de ce qui permet une indépendance de contrôle. S'il existe un problème postopératoire entre la sortie et la visite à six semaines, le patient peut contacter directement l'hôpital et le service d'arthroplastie qui orientera le patient en fonction du problème. Dans le cas d'un problème compliqué, tel par exemple une infection postopératoire le patient sera transférée vers l'hôpital.

DISCUSSION

Le système de récupération fonctionnelle rapide (de type CALEDONIAN) et de prise en charge de la douleur postopératoire nécessite plus qu'une simple infiltration locale et/ou la mise en place d'un cathéter dans le genou. En effet, il s'agit d'une prise en charge multidisciplinaire qui démarre dès la première visite du patient et qui va continuer lors de l'hospitalisation et par la suite pour la visite postopératoire. Le parcours du patient est marqué de rencontres successives avec tous les intervenants de sa prise en charge. Il y a une standardisation du discours et des soins et une grande coordination entre tous les membres de l'équipe.

La réduction du temps d'hospitalisation n'est pas une fin en soi, si les taux de réadmission et les complications sont élevées [7] ! Cependant si objectif est compris par l'ensemble de l'équipe, les patients vont alors bénéficier de soin efficace et plus rapide sans compromettre leur sécurité ni les résultats fonctionnels. De plus la réduction du temps d'hospitalisation est un facteur important de limitation des infections nosocomiales. Ce type de programme nécessite une coopération absolument sans faille entre tous les membres de l'équipe et impose que chaque membre de l'équipe comprennent les objectives recherchées. L'éducation du patient est aussi indispensable au bon fonctionnement de ce système [8, 9, 10]. Les espoirs et les peurs de l'opération seront expliqués au patient depuis le début jusqu'à la fin de sa prise en charge. Le patient, mais aussi tout le personnel impliqué dans son traitement doivent comprendre que la **pose d'une prothèse n'est pas une maladie mais un handicap temporaire qui devrait être résolu par la chirurgie**.

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