ORIGINAL ARTICLE

Mini-invasive computer assisted bi-unicompartimental knee replacement

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Abstract

In the treatment of knee osteoarthritis there are no reports using bi-unicompartimental implants and many orthopaedic surgeons are sceptical about this demanding surgical procedure despite its theoretical advantages in terms of less invasive surgery. The bi-unicompartmental approach also offers the potential advantage of maximal preservation of normal anatomy, with benefits for functional aspects such as gait, muscle activity, and proprioception.

Computer-aided knee replacement surgery has been gaining popularity and an improvement in limb alignment and kinematics has been demonstrated in several studies. During the procedure the surgeon can check both implant position and ligament balance during the full range of joint movements, which helps to reduce the complications traditionally associated with failure in the past.

The authors present a computer-aided technique for performing bi-unicompartimental knee replacement which permits a less invasive alternative for knee replacement surgery.

Keywords: Knee, bi-unicompartmental, prostheses, computer-assisted

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INTRODUCTION

Recently, there has been a lot of talk about mini-invasive prosthetic knee surgery, even if this often really means a smaller skin incision and introducing “keyhole surgery” instruments to implant a total prosthesis that sacrifices both the cruciate ligaments (1). This is the exact opposite of what surgeons of the bi-unicompartmental replacement school have always argued for mini-invasive knee surgery: minimal tibia bone removal, femoral cartilage resurfacing, conservation of the knee ligament apparatus and very minor procedures on the patello-femoral joint (2). Of course, not all the steps of this surgical procedure have been fully established. The indications, technique and the medium/long term results are all still matters for discussion. Despite early failures, the experiences gained from unicompartmental knee replacement (UKR) (3–7) surgery have rekindled an interest in this kind of surgical solution for bicompartimental knee arthritis (8, 9).

Recently, computer-assisted UKR surgery has been developed. This provides the surgeon with new tools for checking limb alignment and ligament balance during the procedure and thus reduces the complications which have been associated with failures in the past (10). Compared to total joint replacement, bi-unicompartmental prosthesis can correct joint deformity three-dimensionally, without harming the ligament apparatus or having to use intra-medullary instrumentation with the minor risk of bone loss and unsolvable joint infection. There are also practical benefits for both the patient and the surgeon, which include:

- reduced blood loss even in simultaneous bilateral implants
- lower risk of vein thrombosis and sepsis

- decreased use of general anaesthesia
- minor lateral compartment lift off due to preservation of the anterior cruciate ligament (11)
- the chance to use all polyethylene tibial components;
- no wear on postero-medial polyethylene surface (edge-loading), due to the presence of an intact anterior cruciate ligament (ACL) that prevents any posterior subluxation of the femur (12)
- no effect on articular muscle sensitivity and proprioception (13);
- shorter hospital stay with more complete and faster articular recovery

Obviously all these advantages indirectly cause a reduction in medical costs and better economic resource management (14, 15).

The literature contains many indications for UKR (3, 5, 6), but clear protocols for bi-unicomparmental implants have yet to be published. In Italy in 1995 a society of orthopaedic surgeon with a particular interest in UKR (GIUM: Gruppo di studio Italiano degli Utilizzatori della Monocompartimentale) was founded to address bi-unicompartimental implant indications (2, 8). Using similar indications for UKR this group has identified typical selection criteria for bi-UKR:

- bi-unicompartmental arthrosis
- asymptomatic patello-femoral joint
- range of motion greater than 90°
- axis deviation lower than 10°
- no important anterior or posterior laxity
- no articular systemic diseases (rheumatoid arthritis, haemophilia, etc.)
- no severe postural deficiency

Other exclusion criteria have subsequently been recognised, including the elderly patient. However, bi-unicompartmental prosthesis has moved in the opposite direction to UKR. Originally indicated for selected young patients, such as those with intra-articular bicompartimental deformity following fractures of tibial plateau, it slowly began to be used as a treatment for atraumatic arthritic knees in older patients. Although not recommended in obesity, bi-UKR can be implanted in overweight patients provided they are motivated to lose weight. The operation often helps patients to return to physical activities that had been interrupted previously by pain or limb dysfunction.

Due to the minimally invasive approach, a bi-UKR implant can be considered as a practical solution even in selected patients with light ACL insufficiency and an incomplete range of knee motion. However there are also absolute contra-indications to bi-UKR implantation:

- the terrible trio: Obesity with Varus in Osteoporosis (OVO)
- inflammatory rheumatism
- significant and symptomatic patello-femoral arthritis
- serious combined laxity
- flexion rigidity higher than 10°

PRE-OPERATIVE PLANNING

Preoperative planning starts from the premise that the thickness of the prosthesis should correct the joint deformity and approach the most damaged compartment first. We therefore have to determine the deviation angle of the lower limb and the minimum thickness of the prosthetic components (femoral component + tibial component + polyethylene or polyethylene and metal back). For this purpose a pre-operative standing X-ray of the lower limbs in full weight-bearing with both patellae and ankles pointing forward is taken. The axial deviation angle in varus or valgus is calculated and subtracted from the minimum thickness, expressed in millimetres, of the prosthesis to give the minimum tibial bone cut required. For example, for a valgus arthrosis of 8° and a prosthesis thickness of 11 mm, a tibial bone resection of 3 mm (11 mm–8 mm) would be required.

The guidance of the navigation system permits us to know exactly how much tibial bone to cut, bringing the femoral-tibial axis back to 180°. The bone resection of the other compartment is judged during the operation, once the trial components have been applied on the basis of the ligament balance and the available joint space.

SURGICAL TECHNIQUE

Since 2001 we have used a CT less computer assisted navigation system (Orthopilot®, Aesculap, Tuttlingen, Germany, version 2.0 and 4.0) in more than 360 joint replacements (knee and hip). The basic surgical procedure used for these replacements is as follows:

Step 1: Prepare the surgical field as you would for a total prosthesis. The patient should be in supine position at the bottom of the bed with the feet outside, leaving the knee to be flexed at 90°. Place a support by the side of the thigh to keep the lower limb in position with the knee flexed. In this way the surgeon operates in front of the patient and can therefore check the mechanical axis constantly

Step 2: We always position a metal locator in the centre of the hip for limb alignment reference during the surgery in order to keep a constant check on axial adjustment and on the correct positioning of the prosthetic femoral component (an X-ray of the hip provides the position of the metal locator).

Step 3: Under anesthesia the surgeon should evaluate the deformity and how much can be corrected.

Step 4: The skin incision, with the limb flexed at 90°, should not exceed 11 to12 cm in a median or paramedian medial direction. The patella should be only retracted and not dislocated.

Step 5: Approach the most damaged compartment, removing the meniscus but leaving the posterior wall intact.

Step 6: Position the support screws for the IR reflecting diodes (LED) of the computer scanner with tiny skin incisions of 1 cm. Locate one on the femur and one on the tibia, both 10 cm away from the joint line. A third diode will be applied to the foot, clipping it to an external metal support fixed by an elastic band. Proceed with the data acquisition of the inferior limb using the computer. By moving the limb and using mathematical models, the navigator determines the axis which goes through the centre of the femoral head, the centre of the knee and ankle. With a mobile pointer, acquire the deepest point in the more damaged tibial plateau, then the deepest point of the other tibial compartment, the centre of the tibial plateau, both the posterior femoral condyles, the superior femoral cortex, and the medial and lateral epicondyles, following the instructions on the screen step-by-step.

Step 7: With the data recorded on the screen, the surgeon can calculate the deformity and how much can be corrected. Data processing empowers the system to produce on-screen information related to the mechanics in frontal and lateral projection within the entire given range of movement see Figure 1. Furthermore it suggests implant size, based on the extent of bony resection and the deformity and tri-dimensional implant alignment.

Step 8: The deformity should always be reducible, but in cases where it is not the surgeon should proceed with a slight release of the ligaments under the direct control of the system.

Step 9: Position the tibial cut guide and connect with a mobile diode to the computer see Figures 2 and 3. The height of the resection is based on the pre-operative planning calculations, its orientation (varus-valgus), and is guided and checked on the display. The slope will be almost normal at about 5°. Because knees with an intact ACL have a reduced articular space in flexion, this needs to be enhanced by the slope and the cut of the posterior femoral condyle. After fixing the guide, continue using an oscillating horizontal blade for the vertical cut, near the ACL insertion point, moving in an anterior-posterior direction. Then change to a "lamellate" blade for the horizontal bone cut.

Step 10: After the removal of the bone block, insert the tibial trial component. The size of the component should be equal to amount of the resected bone and the height depends on the deviation axis correction either in flexion or in extension. The computer allows the correct alignment to be checked throughout the range of

Figure 1 Data processing empowers the system to produce on-screen information related to the frontal and lateral projection within the entire given range of movement.

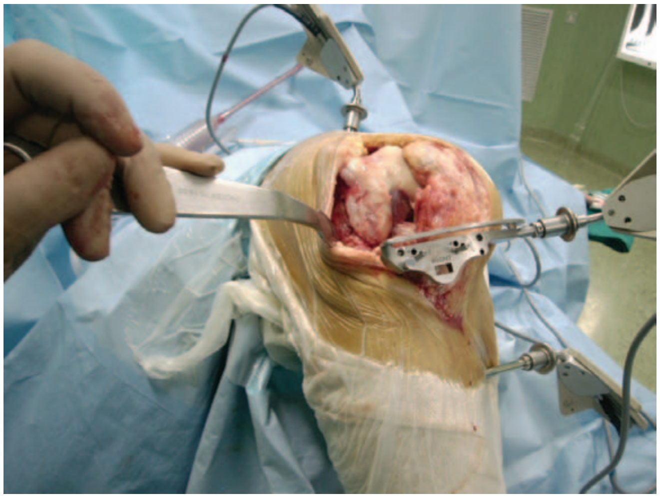

Figure 2 The position of the tibial cut guide and connection with a mobile diode to the computer.

Figure 3 The height of the resection is based on pre-operative planning calculations, its orientation (varus-valgus), and guided and checked on the display.

motion. With the knee extended, mark the front edge of the tibial trial component on the femoral condyle, to check the size of the femoral component.

Step 11: A cutting guide is used on the femoral condyle. It must be positioned parallel to the tibial component and perpendicular to the mechanical femoral axis on the largest contact surface between the components for the whole range of knee motion. Remove the femoral-condylar cartilage, and prepare the holes for the pegs of the femoral implant.

Step 12: Position the trial components, check the mechanical axis and the ligament balance, always reading the values and the morphology of the inferior limb in motion on the computer screen.

Step 13: Having achieved a correct alignment without ligament tension, the other femoro-tibial compartment should be approached under the control of the navigation system. Choose the height of the cut on the basis of space (in terms of flexion and extension). In any case it must be less than 11 mm (prosthesis thickness − deviation angle − articular space = minimum cut).

The latest version (4.0) of our navigation system provides distracters which tense the ligaments and open the articular space according to values expressed in mm. This is particularly helpful in flexion where the joint space is reduced and we have to act both upon the posterior slope and the osseous resection of the posterior femoral condyle see Figures 4 and 5.

Step 14: Position the femoral trial components and decide on the definitive tibial thickness, basing the decision on the optimum ligament balance in terms of extension and flexion and mechanical axis without procurvation or recurvation. Everything is shown on computer in numeric values and visualized by a schematic representation of the lower limb.

Step 15: We first implant the two tibial components and then the femoral one. The limb should be extended and compressed against the chest of the operator to complete the operation see Figures 6 and 7. A final recording of data for the personal

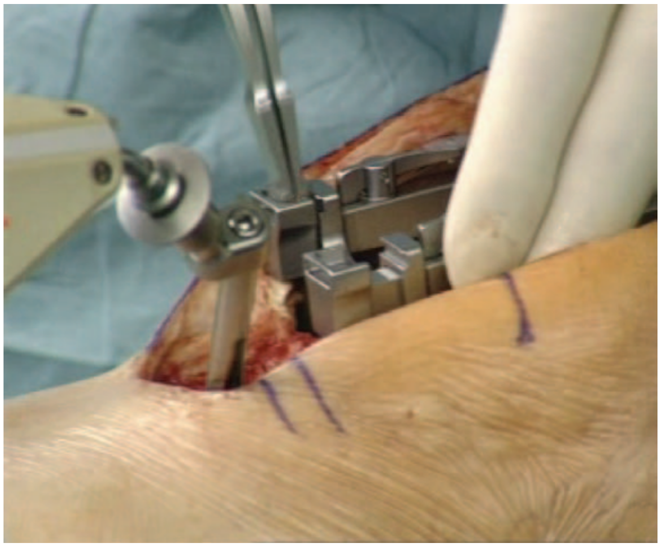

Figure 4 The latest version of the navigation system provides distractors which tense the ligaments and open the articular space.

Figure 5 On the display the surgeon can assess the tension between the 2 compartments according to values expressed in millimetres.

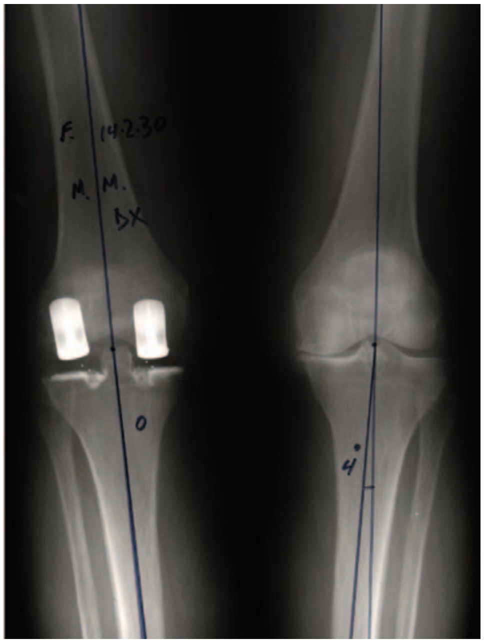

Figure 6 Final result with a good alignment of the implants in the frontal plane.

computerised file card of the patient completes the procedure.

CONCLUSIONS

For decades, pioneering surgeons have experimented with less invasive joint replacement procedures involving smaller incisions and non-traditional surgical approaches. Recently there has been a renewed interest in these techniques because of the availability of new implants which respect both the bone stock and the soft tissues.

Figure 7 Final result with correct patella position in the centre of the femoral groove.

The literature does not contain any reports of bi-unicompartimental knee replacement and many orthopaedic surgeons remain sceptical about this demanding surgical procedure despite its theoretical advantages in terms of less invasive surgery. It has been assumed that the implantation of two sledge prostheses on the medial and lateral condyles could not change proprioceptive abilities (12, 16).

Even in their first experiences using bi-unicompartimental prosthesis the authors experienced some complications such as the detachment of the bone block tibial spines due to unbalanced cruciate ligament tension. Furthermore, limb alignment with traditional UKR alignment systems has always been less accurate in comparison to total knee replacement (TKR) guides, with a limb axial misalignment of >3° being a recognised potential cause of failure (17, 18).

Recently, computer aided surgery has been introduced into orthopaedic practice to assist the surgeon in improving limb alignment, implant positioning and kinematics. In replacement surgery, a reduction in the number of misaligned implants in navigated TKR compared to conventional TKR has been demonstrated in several studies. However, the early studies of computer aided orthopaedic surgery involved wide surgical approaches and bone resections (19–21). New navigation techniques have been developed to address the need for less invasive surgery without influencing the accuracy of the procedure. It is now possible to precisely determine ligament tension during the full range of knee movements and to avoid both excessive bone resection and soft tissue release. In computer assisted bi-unicompartimental knee replacement the surgeon knows exactly how much bone should be resected according to the soft tissue tension or how much release to perform according to the joint space in all positions of the knee. In addition, in their series, the authors did not experience any fearful complications, which are often used as an argument against this innovative procedure. In the author's opinion, a bi-unicompartimental knee replacement associated to a navigated technique is a safe surgical procedure with real advantages compared to traditional implants for the treatment of knee arthritis.

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