9 The Bi-Unicompartmental Knee Prosthesis

Sergio Romagnoli, Francesco Verde, Michele Corbella, and Sara Zacchetti

9.1 Introduction

The bi-unicompartmental knee prosthesis [1-5] is a system that uses two independent components, femoral and tibial, to preserve the tibial eminentia with the anterior cruciate ligament (ACL). Although in the majority of prosthetic knee systems the cruciate ligaments are sacrificed or only the posterior cruciate ligament (PCL) is preserved, a long-term research objective has been to reproduce the normal articular kinematics of the knee, replacing only the worn areas while respecting the capsule and ligaments (Fig. 9.1).

The recent development of tissue-sparing surgery has given new impetus to the utilization of prosthetic systems that respect the undamaged capsuloligamentous structures of the knee. This type of implant, while not an entirely novel knee prosthesis, represents the evolution of the first experiences of Marmor, Gunston, and Lubinus, whose principles remain valid in many aspects of biomechanical and gait analyses.

9.2 Epidemiology

The presence of the ACL in the treatment of bicompartmental arthritis limits the surgical options. Of course, the link between the ACL and its mechanical function must eventually be established. We have carried out survivorship studies of a bicompartmental prosthesis and the unicompartmental Allegretto (Zimmer), with 10-15 years of follow-up [6]. In addition, we have evaluated many other long-term unicompartmental survivorship studies reported in the literature (Goodfellow, Berger, etc.). The results are consistent, confirming the long-term stability on anteroposterior (AP) views. This shows that the ACL is able to maintain the same mechanical function over a period of years. In fact, in our study, in which 124 patients received a unicompartmental prosthesis, there was only one case of failure due to ACL deficiency. With patient age as a criterion, among 500 cases of total knee arthroplasty (TKA), 7.6% of the patients were < 55 years of age, 25.8% were 55–65 years of age, 39.5% were between 65 and 75 years of age, and 27.1% were over the age of 75. This means that 33.4% were below 65 years of age and thus had a high functional demand. Within this group, 29.8% had an intact ACL and were therefore candidates for cruciates-preserving prostheses.

9.3 Indications

Our indications are: patients with femorotibial degeneration but asymptomatic with respect to the patella, cruciate ligaments integrity, flexion deformity < 10°, varus-valgus deformity < 15°, range of active movement (ROM) > 90°, and tibial bone defect < 12 mm [1-4]. Radiographic evaluation is based on standard AP, lateral, and skyline projections demonstrating femorotibial degeneration higher than grade I and femoropa-

S. Romagnoli (✉)
Galeazzi Orthopedic Institute
Milan, Italy
E-mail: sergio.romagnoli@libero.it

N. Confalonieri, S. Romagnoli (eds.), *Small Implants in Knee Reconstruction*,
DOI 10.1007/978-88-470-2655-1_9, © Springer-Verlag Italia 2013

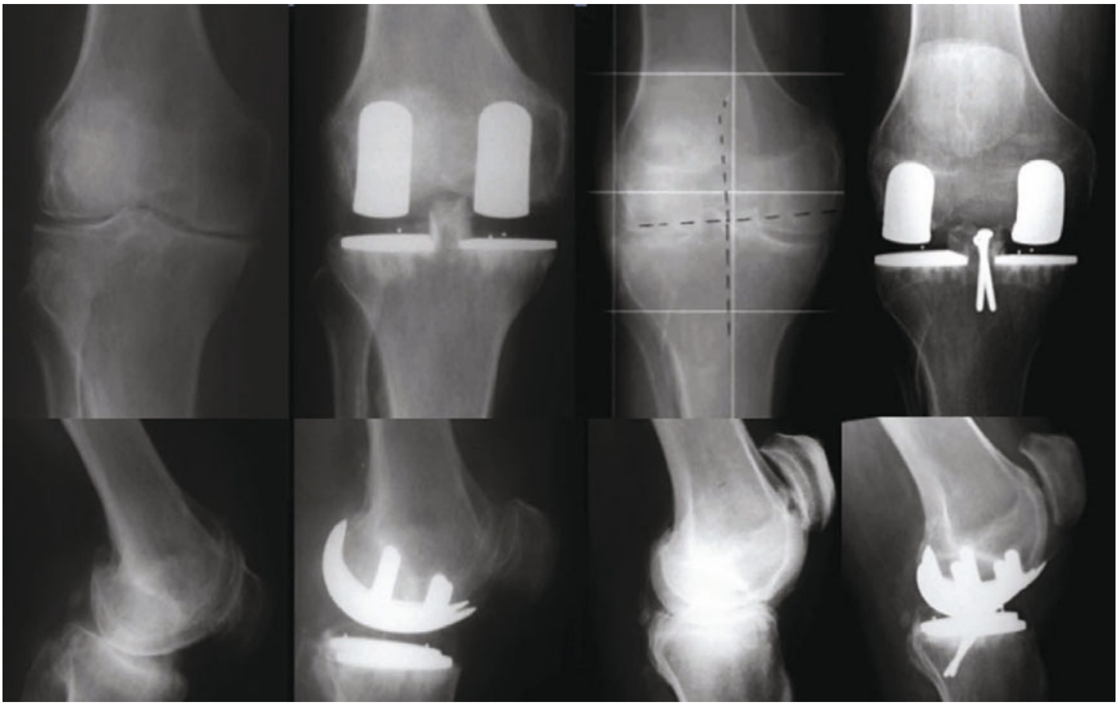

Fig. 9.1 Two bi-unicompartmental implants: *left* at 17 years of follow-up of a 63-year-old male patient; *right* at 15 years of follow-up of a male patient with spina bifida

tellar involvement lower than grade II according to the Ahlback scale. Also, on a weight-bearing long AP X-ray view the mechanical axis can be calculated, showing the correct range of deformity. In some cases magnetic resonance imaging shows features of instability such as ACL deficiency and patellofemoral status. Clinically, the knee must be quite stable and only a mild laxity due to cartilage wear is tolerated. Femorotibial signs of disease are generally present, such as pain while walking and doing stairs or effusion. Patient age and weight are not limits, but this procedure is particularly recommended for young patients (< 65 years) with a good level of activity and a BMI < 32. In fact, a bi-unicompartmental knee replacement (UKR) prosthesis is an option when a high performance of the knee is requested by young patients. In some well selected cases, when bi-femorotibial compartment degeneration is a correct bi-UKR indication but ACL deficiency represents a clear limit, an ACL reconstruction procedure is possible in men under the age of 60 years. Secondary patellofemoral joint degeneration with anterior pain should be kept in mind in patient selection. The standard of evaluations are: symptomatology, X-ray evaluation of the alignment and possible overload, and the intraoperative observation of third or fourth degree chondromalacia. Symptomatology, only if associated with a second parameter, such as X-ray or intra-

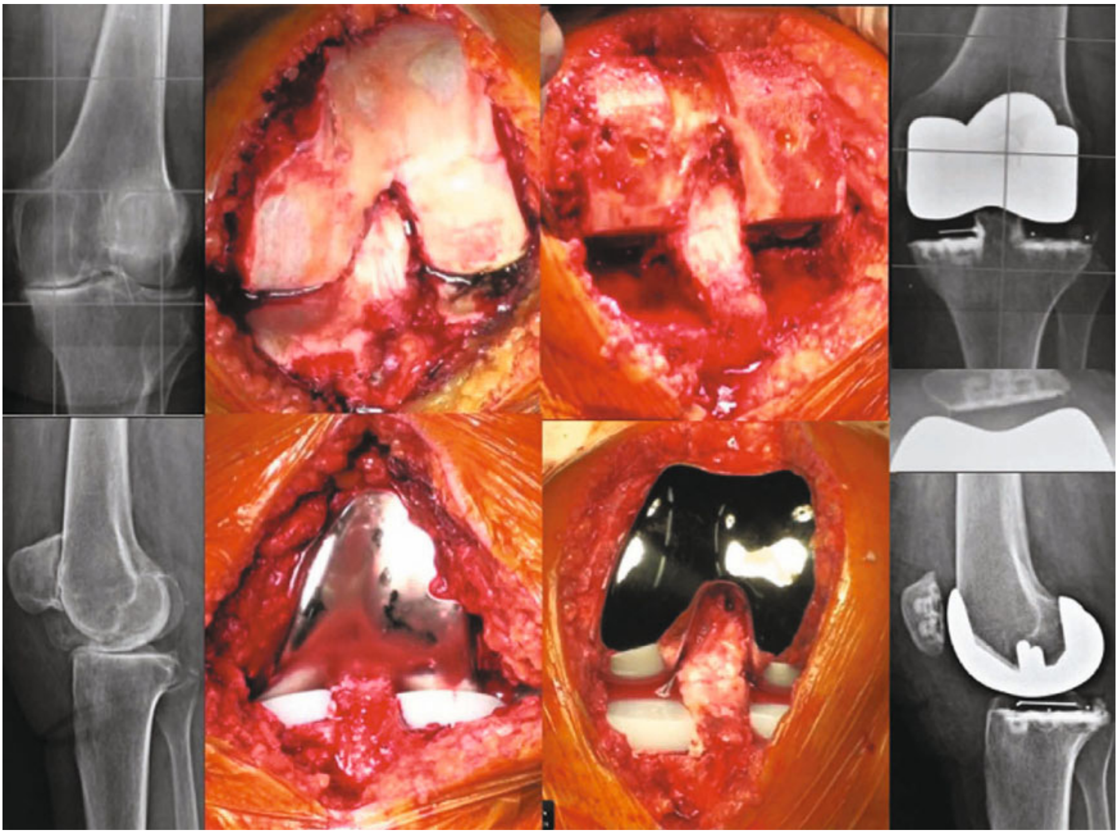

Fig. 9.2 Bi-unicompartmental implant with a bicondylar femoral component in a 61-year-old female

operative findings, is a clear limit to the use of independent unicondylar femoral components. In these cases the alternative is a bicondylar femoral component that also covers the trochlear surface or the inclusion of a patellofemoral prosthesis (Fig. 9.2).

Sometimes bi-UKR can be the result of a UKR revision due to late degeneration and pain in the not treated femorotibial compartment [3, 4]. Obviously, in this kind of prosthesis, performed over the course of years, the previous implant must be stable and the only contraindications are polyethylene wear and ACL deficiency (Fig. 9.3).

Contraindications are active inflammatory arthritis, ligament instability, severe deformity, and fractures if the bone defect is > 12 mm.

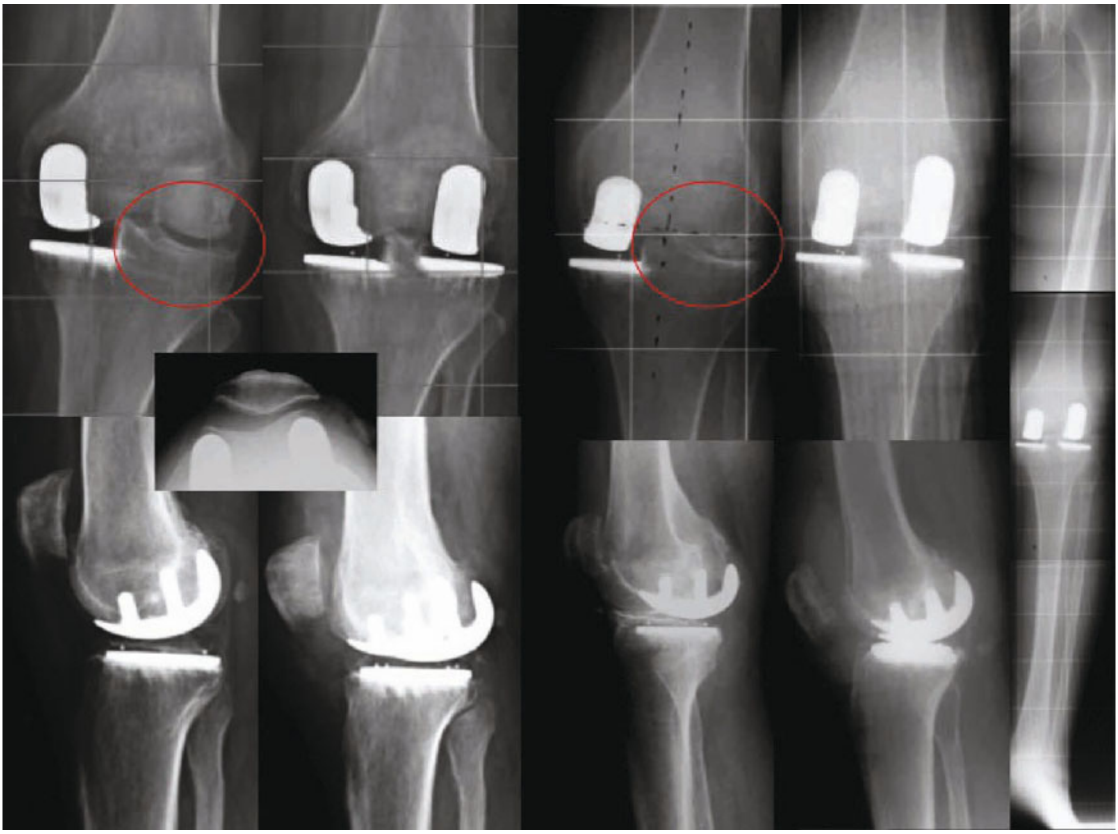

Fig. 9.3 Two cases of a bi-unicompartmental implant as a result of UKR revision: *left* at 20 years of follow-up an 84-year-old male patient; *right* at 15 years of follow-up of a 74-year-old female patient

9.4 Surgical Technique

Bi-UKR uses the same surgical technique as UKR but it is applied to the medial and lateral compartments. Two different approaches are possible: a double mini-skin incision or an isolated medial parapatellar mini-invasive approach.

In the first option, the procedure begins in the compartment of the deformity; once it has been corrected with the implant trials, the other side is addressed. An advantage of this solution is the possibility to further reduce the quadriceps aggression. Thus, essentially, there are two independent implants. The patellar vascularization, in this case, is guaranteed by respecting the superomedial area (Fig. 9.4).

The second choice relies on a mini-invasive parapatellar medial incision of 8–10 cm. In this case, a mini mid-vastus incision allows patellar subluxation, well-exposing the medial and lateral compartments and avoiding patellar eversion (Fig. 9.5). Once the compartments are exposed, surface bone cuts are performed with the tibia first technique.

Tibial cuts are performed, with an oblique cut 15–20° along the AP axis in the medial compartment and 10–15° along the lateral axis. The horizontal cut must be perpendicular to the epiphyseal axis, in order to respect the height and obliquity of the joint line while avoiding any consequent release. In the majority of cases, the tibial cut in the sagittal plane (slope) must differ between the two compartments, lateral 0–3° and medial 3–6°, in order to reproduce the anatomical preoperative slope and respect PCL stability. Once the tibial resection has been completed, the asymmetric features of the tibial plateau must be considered. The lateral compartment is more symmetric than the medial and semicircular compartments regarding

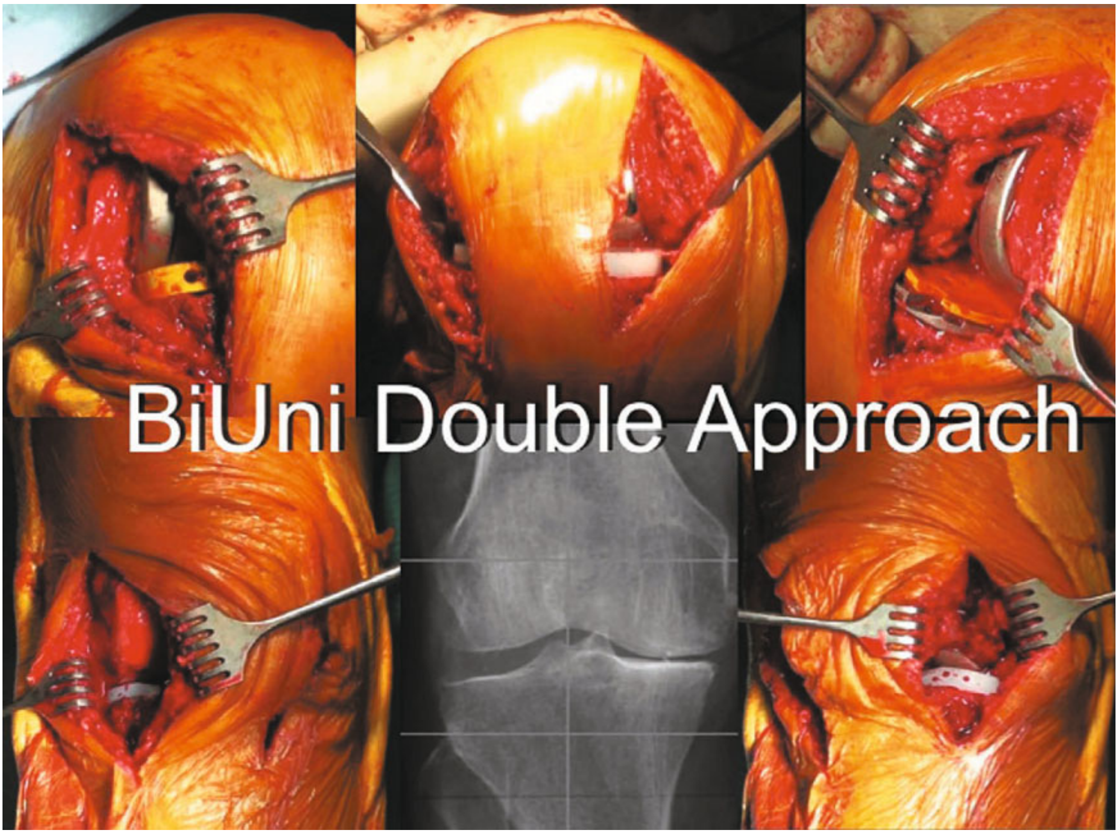

Fig. 9.4 Double mini-invasive approaches: parapatellar, medial, and lateral

their shape. It is thus better to utilize a dedicated prosthesis with a more semicircular shape as it is much more adaptable, allowing uniform coverage of the lateral tibial surface (Fig. 9.6).

The next step involves checking the stability in extension with trials and marking the anterior limits on the femoral condyles to fit the limit of the right anterior position for the femoral cutting guide. We perform the distal cut in extension and the posterior cut in flexion using two different tensor-guides that calibrate the same amount of resection, obtaining a balanced flexion-extension gap. First, the distal cut in extension indicates the desired degree of stability; the tensor is adjusted to avoid overcorrection and release. Subsequently, with the knee in flexion, the same calibrated amount of tension and resection is performed on the posterior condyle. Only 2–3 mm are removed from the femoral condyles, corresponding to the same thickness of the prosthesis to be implanted. From the tibial surface, an amount generally between 3 and 7 mm for each compartment is removed, with less removal on the deformity side. This approach explains why the implant can be considered a resurfacing prosthesis. Furthermore, there is no need for further resection because, if the indications are followed, a morphotype correction is not needed. Regarding the position, a component lateralization is necessary.

The components of the prosthesis will be lateralized to maintain perpendicularity on the tibial components in extension and in flexion. Finally, femoral components with different sizes and flexion degrees are implanted, which create two different radii of curvature. This achieves motion and stability with respect to the rotational axis of each compartment [3, 4]. Once the stability has been checked with trials, the sclerotic bone is removed from the surfaces, followed by drilling and component cementation. The lateral tibial component is cemented first, proceeding to the medial and, finally, to the femoral components.

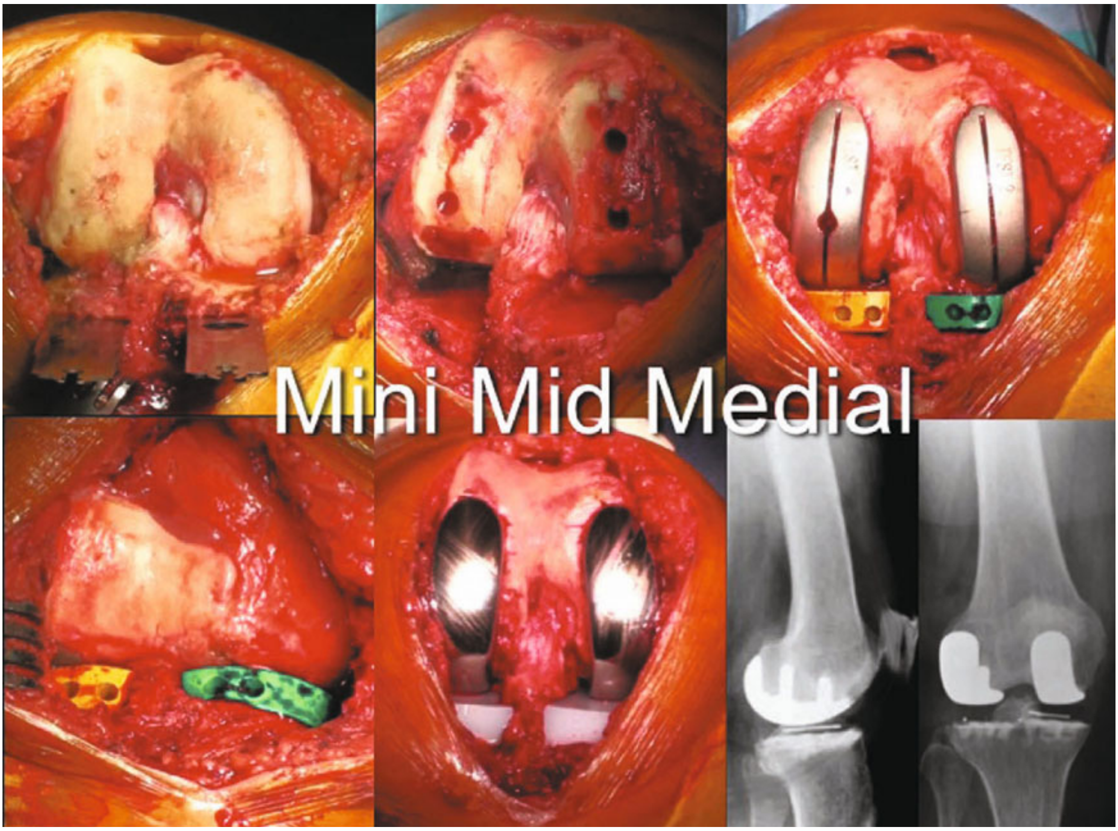

Fig. 9.5 Mini-mid-medial approaches: complete bicompartmental exposure, trials in situ and X-ray control

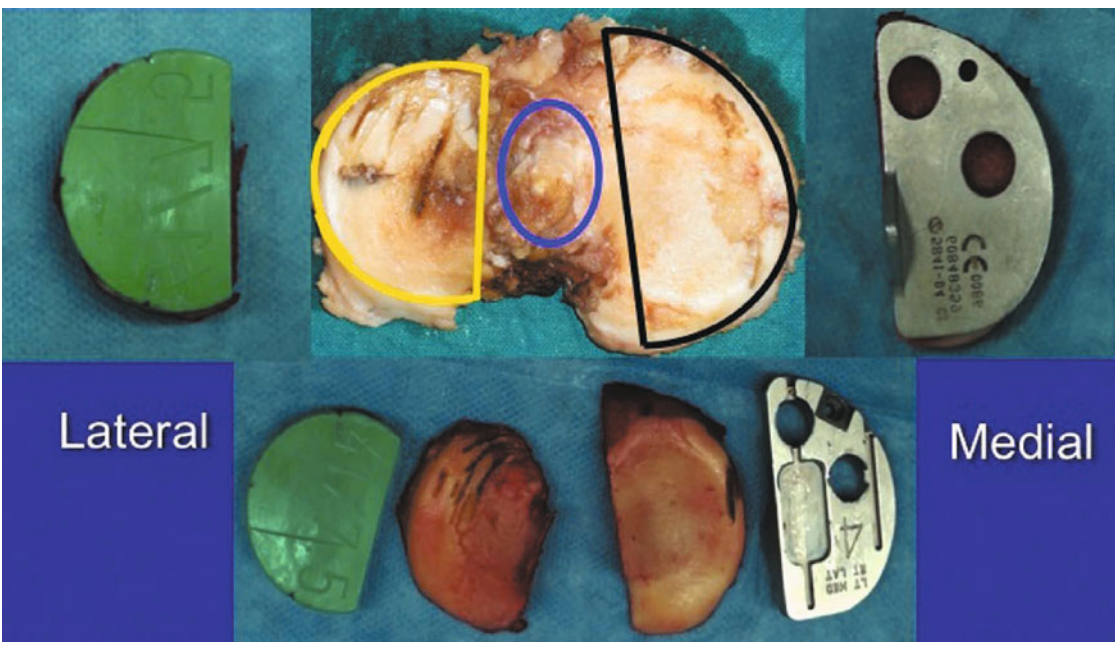

Fig. 9.6 Comparison between the shape of tibial plateau and prosthetic trials

Reconstruction also can be performed in well-selected young patients in whom the only contraindication is ACL deficiency. Our first such patient was operated on in 1996 (Fig. 9.7) [5]. ACL reconstruction was done in an arthrotomy with the patellar tendon. Currently, we prefer an initial arthroscopic step in which the indication is tested, after which the bone tunnel is prepared. Once the graft is positioned, it is fixed to the femur and the bi-UKR technique is then continued. Tibial fixation with screws or staples is done after cementation (Fig. 9.8) [6].

9.5 Graft Selection

We started our experience in 1996, with the patellar tendon. Since 2001, we have implanted UKR and bi-UKR + ACL as first implants in patients with selective indications. We then switched from the patellar tendon to the hamstrings in order to reduce the risk of complications, particularly the risk of joint stiffness and anterior knee pain, as well as the challenges posed by an eventual patellar implant in case of revision with TKR. The first cases, in 2001, involved an arthrotomy with the hamstrings fixed with Rigidfix at the femur and staples at the tibia. Since 2008, we have used cadaver grafts [7], which has reduced the risk of hematoma and medial and posterior thigh pain. The disadvantages are, in addition to the costs, potential problems with osseo-integration and the transmission of an infectious disease from the graft.

9.6 Biomechanics

The preservation of both cruciate ligaments in unicondylar knee arthroplasty is more likely to confer normal knee mechanics and thus enhanced functional improvements, as shown in our recent study carried out at the Istituto Ortopedico Galeazzi in Milano by Romagnoli and Banks [8]. With both cruciate ligaments preserved, total knee arthroplasty should provide better functional benefits than achieved following arthroplasty, which sacrifices one or both cruciates. We compared knee kinematics in patients with well functioning, cruciate-preserving, medial unicondylar and bi-unicondylar arthroplasties in order to determine whether there were differences in knee motion. Eight consenting patients with seven medial unicondylar and five bi-unicondylar arthroplasties were studied using lateral fluoroscopy during treadmill gait, stair climbing, and maximum flexion activities. Custom computed tomography and CAD based models of each knee were used for shape matching to determine the 3D kinematics of the medial unicondylar vs. the bi-unicondylar group (Fig. 9.9).

Maximum flexion in kneeling was 135° ± 14° for unicondylar knees and 123° ± 14° for bi-unicondylar knees ($p = 0.22$). For 0–30° flexion during stair climbing, the medial condyle translated posteriorly 3.5 ± 2.5 mm in unicondylar knees and 4.7 ± 1.9 mm in bi-unicondylar knees ($p > 0.05$). Lateral posterior translation was 5.0 ± 2.3mm in bi-unicondylar knees for 0–30° flexion. For the medial condyle, posterior translation was 1.5 ± 1.6 mm while for bi-unicondylar knees it was 5.1 ± 2.2 mm ($p << 0.05$). Posterior lateral condylar translation in the bi-unicondylar knees was 3.8 ± 3.4 mm (Fig. 9.10).

Retaining both cruciate ligaments in a resurfacing knee arthroplasty appears to maintain the essential features of normal knee motion: femoral rollback and tibial internal rotation with flexion. There were no differences in medial kinematics during stair climbing, indicating similar knee function for the unicondylar and bi-unicondylar groups. The close similarity in the pattern and magnitude of medial and lateral condylar translation in the bi-unicondylar knees was surprising and suggested that a larger lateral translation is typical of the cruciate-intact knee**.** Both condyles moved 5 mm posteriorly on the tibia at heel-strike, indicating a dynamic posterior slide of the femur with impact and weight-bearing. These observations suggest that dynamic stabilizers do not eliminate the envelope of passive laxityof the intact knee caused by external knee loads.

Fig. 9.7 Bi-unicompartmental implant plus ACL reconstruction performed in 1996 with the patellar tendon in a 54-year-old male patient, an ex-professional soccer player

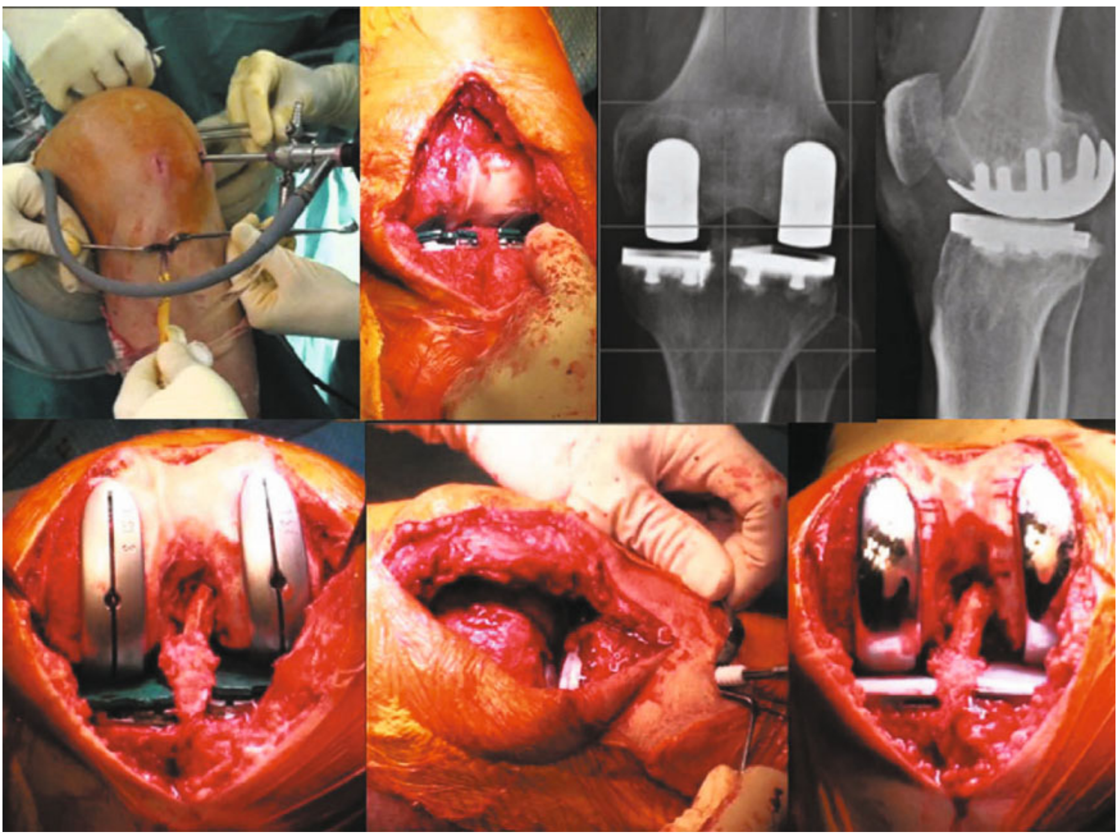

Fig. 9.8 Bi-unicompartmental implant plus contemporary ACL reconstruction: surgical steps

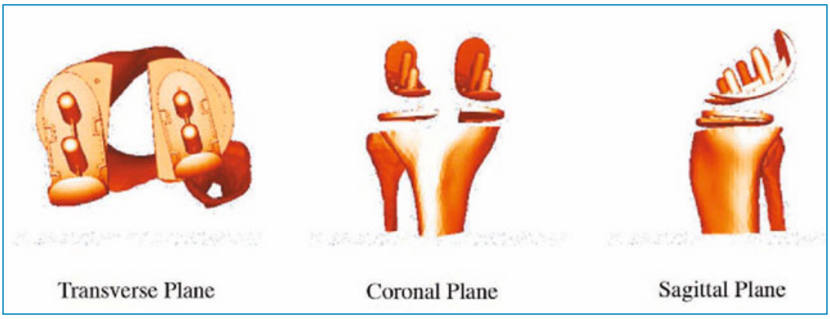

Fig. 9.9 Computed tomography and CAD based models: the knee is in the "neutral" position with respect to the tibial anatomic planes

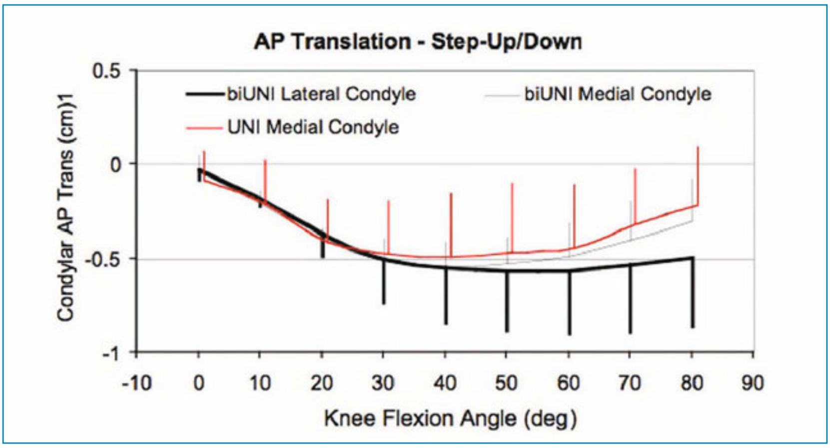

Fig. 9.10 Anteroposterior (AP) condylar translation during step activity in seven unicondylar (UNI) and five bi-unicondylar (biUNI) knees. There were no significant differences in medial translations between UNI and biUNI knees, nor was either medial or lateral translation different in the biUNI knees

9.7 Complications

Causes of failure in this procedure can be intraoperative or postoperative. Intraoperatively, malpositioning of the components, intercondylar eminence fracture, incorrect ligament balance, and cementation mistakes are possible complications during surgery. A tibial eminentia fracture that occurs intraoperatively can be stabilized with two divergent cortical screws, which must be fixed before cementation. Complications following surgery include patellofemoral joint degeneration or secondary ligamentous degeneration-laxity, aseptic component loosening, and polyethylene wear. Septic loosening has the same incidence as in other prosthetic procedures [3-4].

9.8 Patients and Methods

From January 2001 to January 2010, 71 bi-unicompartmental knee arthroplasties were performed by the senior surgeon of our institution in 68 patients, who were followed-up prospectively. The average follow-up was 6 years (maximum 11). The patients were selected based on clinical and radiological symptoms and signs. Clinically, indications for surgery were: knee pain, no femoropatellar joint symptoms, < 10° fixed flexion contracture, and range of motion > 90°. The patients did not have inflammatory arthritis, hemochromatosis, hemophilia, parapatellar tenderness, patellofemoral joint symptoms, or joint instability. The patient population consisted of 41 females and 27 males with an average age at surgery of 67 years (range: 47–81 years). Their average height was 167.3 cm (156–183 cm) and their average weight was 74 kg (53–92 kg) (Fig. 9.11).

One patient was previously treated by high tibial osteotomy (HTO), two had necrosis of both femoral condyles, one had a post-tibial plateau fracture, one had spina bifida, one had poliomyelitis but with good muscle control, and one had an ACL lesion treated with a contemporary reconstruction using a cadaver graft. At surgery, the patients had no more than type I femorotibial involvement and degeneration according to the Ahl-

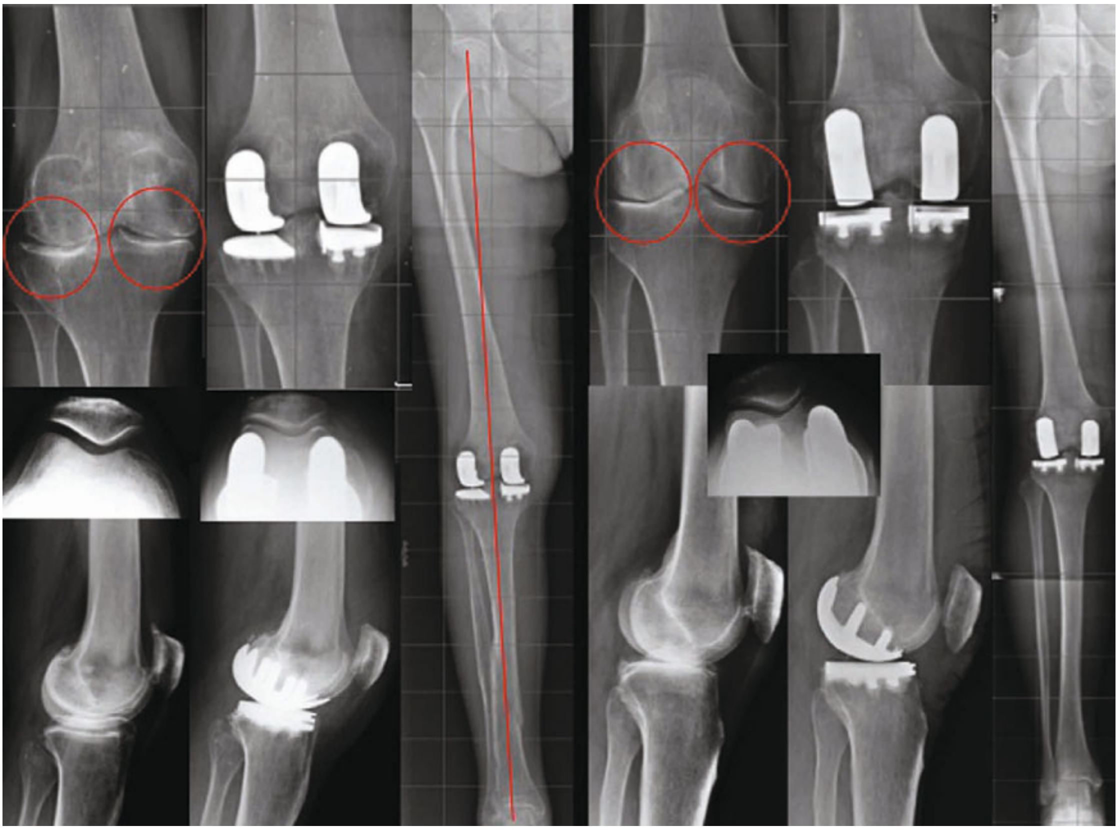

Fig. 9.11 Two cases of bi-unicompartmental implants: *left* a 69-year-old female; *right* a 64-year-old male

back classification. The patients were followed-up yearly for a period of 3 years and then every 2 years. At the most recent follow-up of 71 knees, all 68 patients were evaluated: 65 (68 knees) clinically and radiologically and three only by phone interview as they were not able to visit the clinic. All patients expressed personal satisfaction. Postoperative knee function was evaluated using the Hospital for Special Surgery Knee Score before surgery and at last follow-up. An X-ray was taken for AP weight-bearing, lateral, and patellar skyline views of the knee. Radiographic evaluation included the mechanical and anatomical axes, the cement interface, and the prosthesis-cement interfaces in each of 11 zones, searching for the presence and extent of radiolucencies. These were considered to be progressive if there was either an increase in size or the radiolucency had progressed from one zone to an adjacent zone with time. Radiographically, in addition, the opposite compartment and the patellofemoral joint were evaluated Preoperative X-rays served as the baseline for the evaluation of radiographic progression of the patellofemoral joint, which if present was graded on a four-point scale. Grade 1 radiographic change was defined as no measurable joint-space loss but with radiographic changes such as osteophytes. Grade 2 radiographic changes were defined as up to 25% joint space loss. Grade 3 radiographic changes were defined as up to 50% joint-space loss. Grade 4 radiographic changes were defined as > 50% joint-space loss. Kaplan survival analysis was used to assess the long-term results using revision as the end point.

9.9 Results

Clinically, the average preoperative Hospital for Special Surgery Knee Score was 59 points (range: 42–68 points), which postoperatively improved to 92 points (range 70–100 points). The

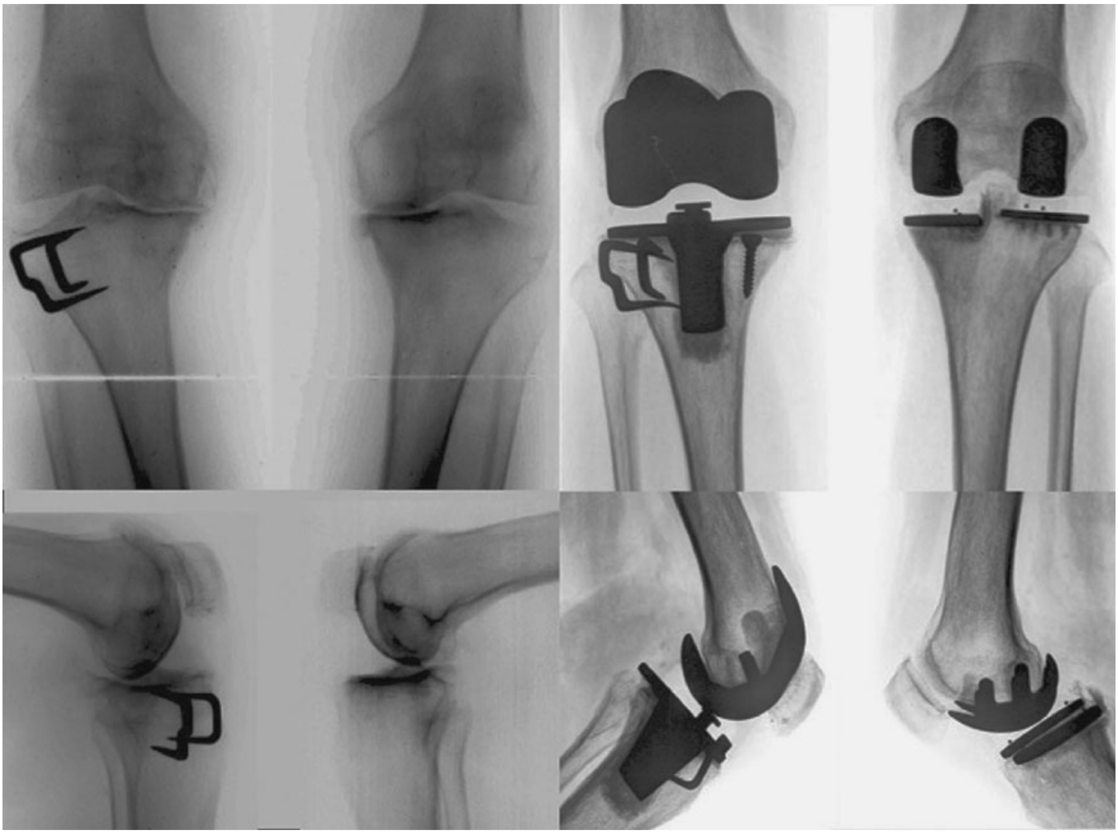

Fig. 9.12 Bilateral implant (Bi-Uni) in a left knee at 16 years of follow-up

average preoperative ROM was 104.7° (range: 80–130°) At the final follow-up, the average ROM was 124.7° (range: 102–136°). In 58 knees, the ROM was > 120°. Sixty-four patients had no pain (94%), while two had slight or occasional pain (3%) (Fig. 9.12).

At the time of the latest follow-up, 64 patients (94%) were enthusiastic regarding the procedure, two patients (3%) were satisfied with the procedure, and in two patients (3%) the procedure failed at 5 and at 5.5 years after surgery.

Radiographically, no component showed evidence of loosening, defined as no change in the position of the components on sequential radiographs. There was no radiographic evidence of osteolysis. The average preoperative deformity ranged from 12° varus to 7° of mechanical axis valgus. The average postoperative alignment was 2,2° of mechanical axis valgus (range: from 3° varus to 2° valgus).

There was no radiographic progression of the patellofemoral joint in 57 knees (80.2%) but 14 knees (19.7%) had grade 2 progression.

There were two revisions (Table 9.1). One, 5 years after surgery, for anterior instability and femoropatellar joint degeneration and the other, 5.5 years after implantation, for continuous anterior knee pain; In the first case, which was probably due to the acquired instability caused by the progressive ACL degeneration, the patient underwent revision because of continuous anterior knee pain. Capsuloligamentous instability was evident as an ACL deficiency; femoropatellar joint degeneration was determined during surgery (Fig. 9.13).

In the second case, rheumatoid arthritis was determined based on a biopsy during revision. In neither case was there component instability or polyethylene wear. No failure was registered among the patients with HTO (n =1), tibial pla-

Table 9.1 Survival of 61 bi-unicompartmental knee replacements

Years since surgery	N. at start	Failure	Width	Lost to FU	N. at risk	Fail %	Succ %	Surv rate	%var	% SE	Cause of failure: rev
0-1	71	0	0	0	71	0.00	100.00	100.00	0.00	0.00	
1-2	71	0	7	0	67.5	0.00	100.00	100.00	0.00	0.00	
2-3	64	0	7	0	60.5	0.00	100.00	100.00	0.00	0.00	
3-4	57	0	10	0	52	0.00	100.00	100.00	0.00	0.00	
4-5	47	1	8	0	43	2.23	97.67	97.67	5.16	2.27	Instability
5-6	38	1	4	0	36	2.78	97.22	94.90	12.77	3.57	Instability
6-7	33	0	7	0	29.5	0.00	100.00	94.90	15.58	3.95	
7-8	26	0	6	0	23	0.00	100.00	94.90	19.98	4.47	
8-9	20	0	9	0	15.5	0.00	100.00	94.90	29.65	5.45	
9-10	11	0	6	0	8	0.00	100.00	94.90	57.45	7.58	
10-11	5	0	5	0	2.5	0.00	100.00	94.90	183.83	13.56	
Total		2	69	0							

FU, follow-up

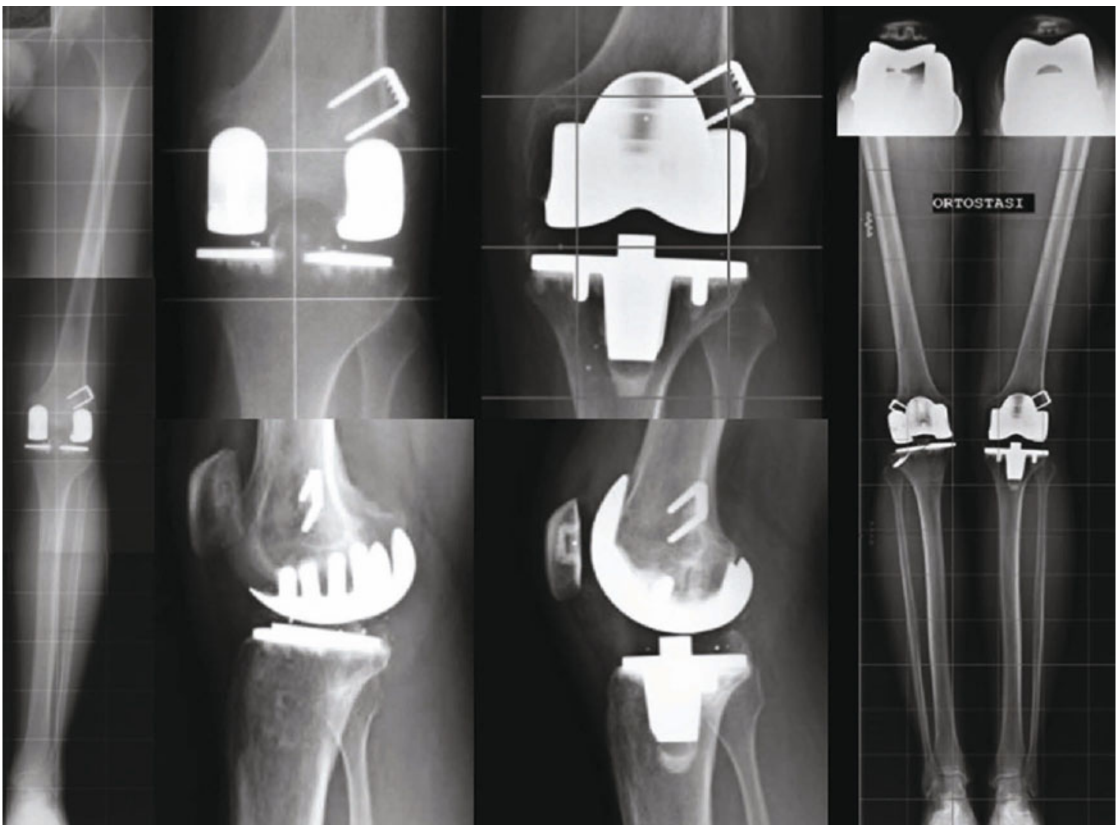

Fig. 9.13 Revision at 5 yrs after surgery due to ACL deficiency and patello-femoral de generation

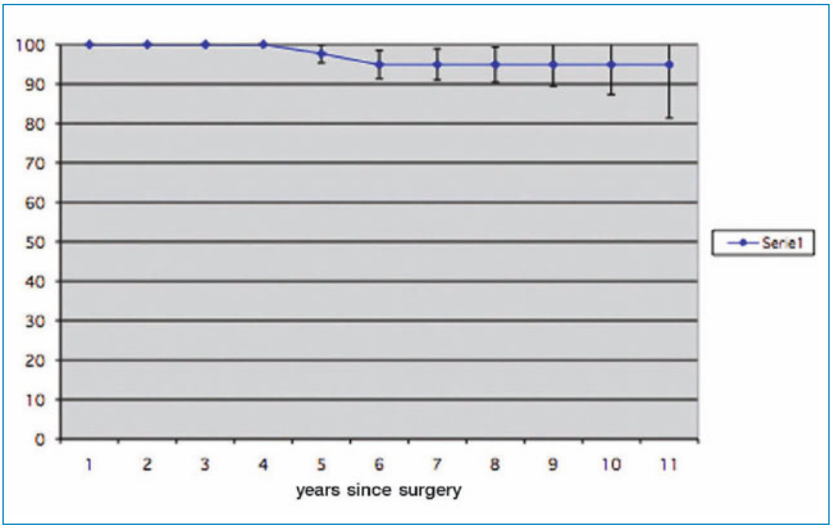

Fig. 9.14 Kaplan-Meier survival curve of bi-unicompartmental knee replacement. See Table 9.1 for details

teau fracture (n =1), femoral condyle necrosis (n = 2), spina bifida (n = 1), poliomyelitis (n = 1), and contemporary ACL reconstruction (n = 1). The cumulative survival rate at 11 years was 94.90% (Table 9.1, Fig. 9.14).

9.10 Conclusions

In attempts to perform truly mini-invasive and tissue-sparing surgery, defined as the preservation or reconstruction of the intact and functional structures of the knee during the implant procedure, Bi-UKR is a possible solution. It is strongly indicated in young, active patients, especially males < 60 years with femorotibial arthritis but an asymptomatic patella and a stable ACL. In these patients, who typically have a high functional demand, this solution allows rapid recovery of daily activity with a very nearly normal gait and a ROM wider than achieved in the best series of TKA. Moreover, the survival curve demonstrates results very similar to those of TKA.

Bicruciate-retaining knee arthroplasty, even if not commonly performed, can provide a high level of function as well as knee kinematics that retain the essential features of the normal knee.

References

1. Romagnoli S, Boniforti F, Cavazzuti G, Castelnuovo N, Verde F (2005) Biomechanik und Arthrose. In: Buckup K (ed) Die unicondylare Schlittenprothese (Unicompartmental Knee Arthroplasty). Steinkopff, Darmstadt
2. Romagnoli S, Verde F, Bibbiani E, Castelnuovo N (2008) La Bimono. G.I.O.T. 34 (suppl. 1)
3. Romagnoli S et al (2007) Bi-uni knee replacement. Basic science, Clinical Repair and reconstruction of articular cartilage defect: current status and prospect. Timeo Editore, Bologna
4. Romagnoli S, Verde F, Bibbiani E et al (2010) Bi-unicompartmental knee prostheses. In: Scuderi GR, Tria AJ (eds) Minimally invasive surgery in orthopaedics. Springer, Heidelberg, pp 327-40
5. Romagnoli S, Camera A, Bertolotti M, Arnaldi E (2000) La protesi Bimonocompartimentale con rispetto ricostruzione del LCA. Il Ginocchio, vol.19
6. Romagnoli S, Verde F, Eberle RW (2006) 10 year minimum follow-up of medial unicompartmental knee arthroplasty with the allegretto prosthesis. JBJS-BR 88-B, Suppl I:100
7. Romagnoli S, Verde F et al (2011) La protesi monocompartimentale con ricostruzione del LCA. In: Confalonieri N (ed) La protesi monocompartimentale del ginocchio. CIC Editore
8. Romagnoli S, Banks SA, Fregly BJ, Boniforti F, Reinschmidt C (2005) Comparing in vivo kinematics of unicondylar and bi-unicondylar knee replacement. Knee Surgery, Sports Traumatology, Arthroscopy. Springer, Berlin