Bicruciate Total Knee Replacement

23

James W. Pritchett

Key Points

Bicruciate knee replacement is an attractive concept because it preserves rather than removes the anterior cruciate ligament and the tibial eminence. Bicruciate knee replacement is not a new procedure, but there are new bicruciate knee implant designs available. There are five key points to consider before deciding to perform a bicruciate total knee replacement:

- Preservation of both the cruciate ligaments during total knee replacement is challenging but results in excellent function and long-term survivorship.
- A total knee replacement with both cruciate ligaments intact results in more normal kinematic and clinical function compared to knee replacements with one or both ligaments resected.
- A bicruciate knee replacement requires less bone and soft tissue resection. A more normal transmission of the weight-bearing stresses is possible compared to other knee replacements.
- Preserving both cruciate ligaments mandates the correct tension on all ligaments. The joint line, knee alignment, and restoration of the surface contours are a complete match to the patient's normal (constitutional or pre-arthritic) knee.
- Paired bilateral studies have shown that patients prefer a bicruciate total knee replacement compared to other total knee replacements. Patients report more normal feel, fewer noise-related complaints, better strength and stability on stairs, and better performance in single-leg weight-bearing activities.

23.1 Introduction

Bicruciate knee replacement offers several functional benefits over other types of knee replacement. It results in a more natural feel with a greater sense of security during weight-bearing flexion, the replaced joint retains more normal biomechanical function, and the knee is stable and capable of an excellent range of motion.

Bicruciate knee replacement also offers several procedural benefits. It is more bone and soft tissue conserving, and it does not transfer weight-bearing stress into the center of the tibia through a medullary stem but loads the tibia in a more physiologic manner. The insertion technique is more demanding but less intrusive because there is no subluxation of the tibia forward on the femur during surgery.

Most surgeons prefer removing one or both cruciate ligaments, allowing the shape of the

J. W. Pritchett (✉)
Department of Orthopedic Surgery, University of Washington, Seattle, WA, USA

C. Rivière, P.-A. Vendittoli (eds.), *Personalized Hip and Knee Joint Replacement*,
https://doi.org/10.1007/978-3-030-24243-5_23

implants to drive the stability and motion of the knee. Also, subluxing the tibia forward is an easy and efficient way to visualize the tibia. However, with better techniques and instruments, resecting the cruciate ligaments is an unnecessary concession to convenience. Some surgeons argue that a useful anterior cruciate ligament (ACL) is not always present or that its kinematic function cannot be restored. For some patients, though, keeping their ACL is the only way to preserve their knee function. Younger and more active patients are presenting for knee replacement surgery. The ACL is intact in more than 60% of all patients presenting for total knee arthroplasty (TKA) regardless of age and stage of disease [1].

23.2 History of Bicruciate Knee Replacement

The first total condylar knee replacement was a bicruciate prosthesis. Dr. Charles O. Townley made drawings of a total knee prosthesis while a resident at Ford Hospital [2]. His design garnered an unenthusiastic reception from Sir John Charnley, a visiting professor in 1948, who claimed there would be too much metal implanted. Townley began using only the tibial component with retention of both cruciate ligaments in 1951 [2] (Fig. 23.1). Other knee implants of the 1950s and 1960s were either hinged or paired compartmental prostheses [3].

Fig. 23.1 This is a photograph of the Townley tibial articular plate used from 1951 to 1971

Seventy-five percent of Townley's articular plate patients had good clinical outcomes. In 1959, Townley added a McKeever patellar prosthesis and resurfaced the femoral condyles and trochlea with polyurethane foam (Ostamer) that had been used as a bone glue for fracture nonunions [4]. This was the first total condylar knee prosthesis (Fig. 23.2). It looked and functioned similarly to total condylar implants introduced in the 1970s [5].

Polyurethane is hydrophilic. The polyurethane Townley used ultimately softened and was absorbed and excreted through the kidneys. Polyurethane was withdrawn by the manufacturer after some reports of failures when used in fracture and arthrodesis [6]. However, none of the knee procedures failed clinically despite using a thermosetting acrylic. Bone has recuperative powers for chemical and thermal exposures. The knees functioned as a hemiarthroplasty after the polyurethane was absorbed. None required revision, and a few patients were followed for more than 30 years with functioning knees [2].

When polyethylene became available, Townley moved the metal component to the femur and used polyethylene for both the tibial and patellar components [7]. Cloutier and others later provided bicruciate knee prosthesis designs and generally with success [8]. Townley refined his bicruciate prosthesis and used it with success for the next 40 years.

23.3 Rationale for Bicruciate Knee Replacement

Normal knee function relies on smooth, uninterrupted motion that is provided by stable, well-lubricated, low-friction articular surfaces. Knee replacement involves compromises between stability and flexibility. For most surgeons, this includes removal of one or both cruciate ligaments [5]. As an alternative philosophy, a bicruciate knee replacement emphasizes minimal bone resection and limited constraint with the goal of allowing more natural movement of

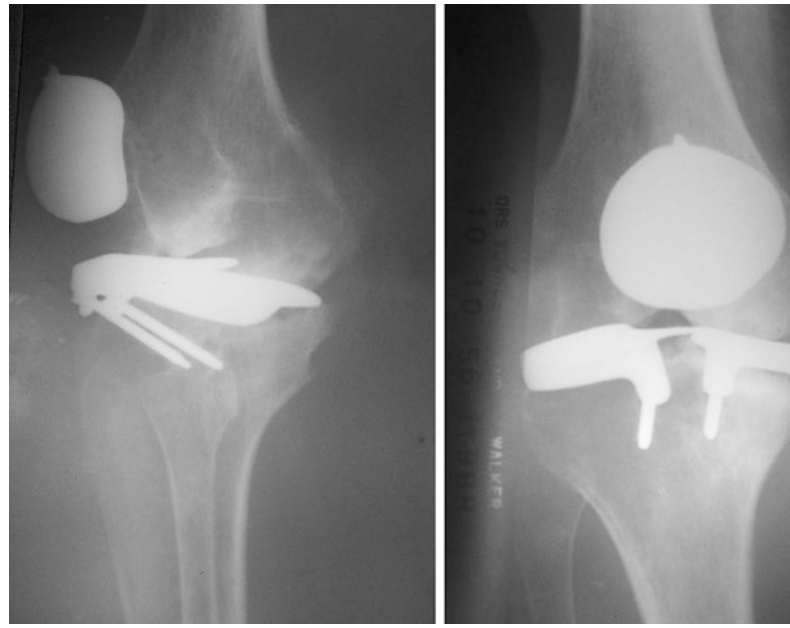

Fig. 23.2 This radiograph was taken 33 years following placement of a Townley tibial plate and McKeever patellar prosthesis. The polyurethane used to resurface the femur wore away, but the clinical function remained good

the knee compared to other prostheses [9–11]. A well-performed bicruciate total knee replacement more closely approximates the function of a normal knee. Resection of the cruciate ligaments is an unnecessary concession to custom and habit.

23.4 General Indications for Bicruciate Knee Replacement

Total knee replacement using any of the contemporary knee prostheses can be expected to improve function, reduce pain, and provide satisfactory implant survivorship. Most studies report that 20% of patients have reservations about the quality of their result even in the absence of complications.

Bicruciate total knee replacement is a demanding procedure. Precise surgical technique is necessary, as well as skill, familiarity with the technique, and the ability to work well in a confined surgical space. Bicruciate knee replacement anticipates that the ACL is functionally intact, although some ACL fibers are inevitably lost to disease. Stability as shown by the anterior drawer and Lachman maneuvers is sufficient evidence that the ACL is competent. Varus, valgus, and flexion contractures up to 15° can be accepted (Fig. 23.3). Age is not a barrier to bicruciate total knee replacement.

23.5 What Are the Best Indications?

Patients who benefit the most from bicruciate knee replacement appreciate the stability during their activities that require confidence in single-leg, weight-bearing flexion. Patients who have had their ACL reconstructed are particularly motivated to retain their ACL and understand its value (Fig. 23.3). A few patients are so committed to bicruciate replacement that they will undergo ACL reconstruction before their knee replacement.

Patients with vascular insufficiency are also motivated to undergo bicruciate knee replacement to avoid added tension on vascular structures that

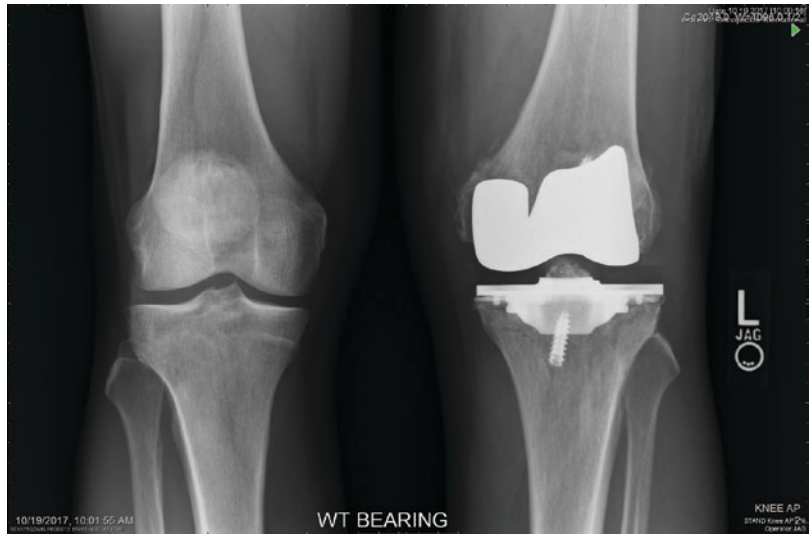

Fig. 23.3 This is a currently available bicruciate total knee prosthesis placed for severe arthritis in a patient with a prior ACL reconstruction

can result from forward subluxation of the knee. Since this is not part of a bicruciate procedure, there is a lower risk of vascular injury. Patients with a blocked medullary space of the tibia can also benefit from a bicruciate replacement since there is no medullary stem. Thus, additional procedures to remove prior fixation implants in the tibia can be avoided.

23.6 What Are the Specific Complications?

Unique complications related to bicruciate knee replacement are fracture of the tibial eminence and rupture of the ACL. Usually, these occur intraoperatively as the knee is brought from flexion into extension. If these complications occur, options are to convert to another type of prosthetic replacement or to repair/reconstruct the ACL or eminence. Screws can be used to secure an eminence fracture. A graft can be used to repair an ACL rupture, but this adds complexity to the TKA. Most commonly, if there is an ACL rupture, conversion to a medial congruent implant is recommended.

Fracture of the tibial baseplate and sometimes the polyethylene occurred in some of the older implants. The fracture has been detected on routine follow-up radiographs. It may or may not require revision based on how well the patient's knee is performing. This complication no longer occurs with forged cobalt–chromium tibial trays.

Loosening of the tibial tray occurred with one recent bicruciate prosthesis, but it was attributed to flaws in the implant design and implantation technique. This implant is no longer in common use [12].

Scar around the ACL resulting in limited motion can occur due to tensioning degenerative ACL fibers during implantation. The tension in these cases is from insufficient tibial or femoral resection or thicker than necessary tibial polyethylenes (i.e., overstuffing). A bicruciate knee should not be placed with the same ligamentous tension that might be acceptable with other designs. The intact ACL will provide all necessary stability. Restoration of motion is achieved by recessing the ACL.

23.7 Alignment Technique

Alignment is critical. Although it looks reasonable to preserve knee anatomy with the kinematic alignment, my personal experience was

using an adjusted mechanical alignment technique in which I usually plan 2°–3° of varus with respect to the mechanical axis of the knee. Most commonly, the tibia is prepared with 6° posterior slope. Extramedullary guides for the tibia are preferred, as the medullary canal of the tibia is not opened in a bicruciate replacement. The medial and lateral tibial plateaus are prepared with separate sagittal and transverse cuts. Conventional instruments typically have been used; but, more recently, robotic techniques have been developed. The instruments do not need to be complex, but a careful stepwise technique is required.

23.8 Stepwise Surgical Technique

Close approximation of the anatomical contours and preservation of the strategic ligaments during implantation are the secrets of success in knee replacement. Bicruciate knee replacement requires a masterful understanding of the patient's knee. Its creativity is from mastering the simplicity of the concept. Ligamentous balancing is performed, but neither cruciate ligament is resected or recessed. Initially, alignment and balance in extension are achieved by correcting the coronal deformity with appropriate capsular and collateral ligament releases.

The femur is prepared first. A spacer is used to assure that a sufficient distal femoral cut has been made. The femoral component is an unconstrained design, and the shape of the condyles simulates a normal knee. The femur is placed in 3° of external rotation. Great care is used to place the anterior flange flush to the trochlea. The femoral component is placed directly on the posterior femoral condyle making sure any remaining cartilage or osteophytes are removed. Throughout the tibial preparation, the tibial eminence is protected by pins using a guide to assure there is no undercutting. The tibial spines and insertions of the cruciate ligaments are left in continuity with the rest of the tibia. The tibial component is placed in slight external rotation following the orientation of the ACL fibers. A spacer block is used again to assure an adequate resection of the tibia, with the goal of using the thinnest tibial inserts of 8 mm. If there are insufficient distal femoral or proximal tibial cuts or inadequate ligament balancing, the tibial eminence can fracture, and/or the ACL can rupture as the knee is moved from flexion into extension.

It is important to have the correct ligament tension at the conclusion of the procedure. The knee should have a smooth, uninterrupted, full range of motion at the end of the procedure. There should be no need to stretch out any remaining contractures.

Preparation for the keel of the tibial prosthesis is made anteriorly. The tibial implant is placed first followed by the femoral component. The patella is prepared to receive a dome-shaped prosthesis. Patellar tracking is verified. Since the joint line has not been elevated and the knee is well balanced, lateral retinacular release is not necessary.

23.9 Clinical Evidence Supporting Bicruciate Total Knee Replacement

Bicruciate total knee replacement has been performed since 1971. There have been improvements in the quality of the polyethylene, the metallurgy of the tibial tray, and instrumentation. Townley first reported the results of 80 bicruciate TKAs in 1973 with good or excellent results in 84% at 2 years [7]. In 1985, he reported on 532 procedures, and 89% had good or excellent outcomes at 1.5–11 years [13]. Tibial loosening occurred in 2%. In 1988, Townley presented his results as his Presidential Address to the American Knee Society [14]. He also introduced porous-coated fixation. The implant survivorship at 16 years post-TKA in 1700 patients was 92%, and 90% of his patients had good or excellent outcomes [2, 7, 13].

The Hermes AC total knee replacement was designed by Cloutier in 1977 [8]. At 22 years of follow-up, the survival rate was 82%, 12% were revised for polyethylene wear, and 4.3% were revised for aseptic loosening. Overall, 87% of patients had good or excellent results. The mean AP laxity was 1 mm [8]. Buechel and Pappas [15] reported that 91% of meniscal-bearing TKAs with bicruciate preservation survived 20 years.

The author [15] conducted a competing-risks survivorship analysis of 537 TKA procedures at 23 years follow-up and found that survivorship was 94%; 5.6% were revised, most commonly because of polyethylene wear. Late ACL ruptures occurred in two patients. The mean AP laxity at 23 years post-TKA was 2 mm with two revisions for instability.

23.9.1 Patient Satisfaction

Implant survivorship is not a synonym for satisfaction. The generally accepted patient-reported outcome measures may not be accurate. Therefore, for the 23-year review mentioned previously [16], I asked five questions (Table 23.1). In response, 96% of patients had their pain relief expectations met, 95% of patients returned to their regular activities, 69% had their expectations about sports participation met, 90% were overall satisfied, and 75% would recommend the surgery to another individual [16].

23.9.2 Patient Preference

Determining a patient's preference is an alternative method to traditional patient-reported outcomes. It offers another way to understand the relative importance of attributes from the patient's point of view. Patient preference studies are concerned with measuring patient values. Patient preferences come directly from the patient without interpretation. Patient preferences are the best way to determine benefit when no option is clearly superior to another and when patients' views vary considerably or are different from the views of the healthcare providers. It is a very powerful tool in assessing outcomes of knee replacement surgery because surgeons have strong preferences about both technique and implants. Surgeons' preferences may not reflect their patients' values.

Comparing patients and procedures is difficult regardless of how carefully the study is designed and executed. Twins, but not clones, have been studied to determine similarities and differences for some medical conditions. In bilateral knee replacement studies, patients serve as their own controls, thus eliminating the effects of personality, age, gender, diagnosis, bone quality, and activity level. If the same surgeon using the same technique, indications, and treatment methods performs the care, then a high level of confidence in the data is warranted [17–19].

The author performed a patient preference study starting in 1987 [19]. There were 640

Table 23.1 Results of patient satisfaction questionnaire [16]

Questions	Met completely (%)	Met (%)	Neutral (%)	Probably not (%)	Not met (%)
1. Were your expectations regarding pain relief met?	78	18	1	1	2
2. Were your expectations regarding return to regular activity met?	53	43	2	1	1
3. Were your expectations regarding return to sports and recreational activity met?	49	20	15	8	8
4. Were you satisfied with your knee replacement?	71	19	8	1	1
5. Would you recommend this surgery to a friend?	75	21	2	1	1

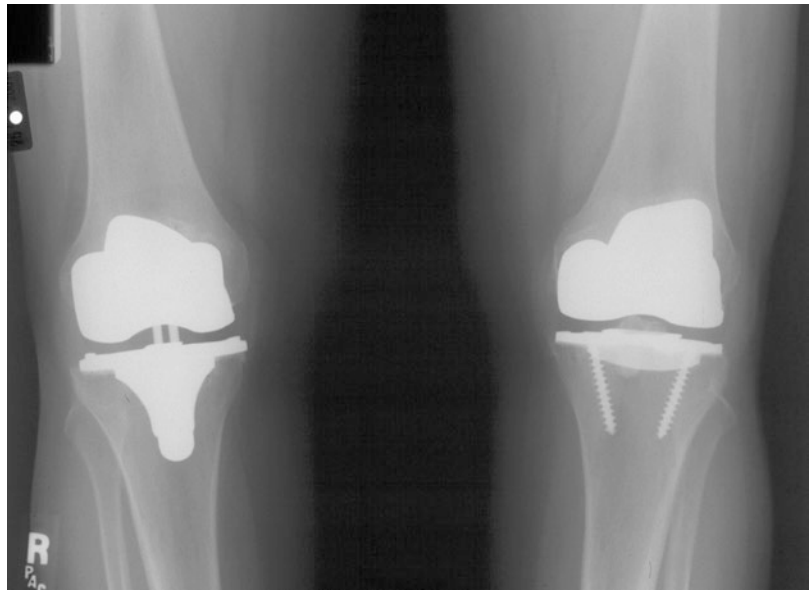

Fig. 23.4 This is a patient with a bicruciate total knee replacement on one side and a contralateral posterior stabilized prosthesis

patients (1280 knees) enrolled prospectively to evaluate patient preferences in total knee prostheses. Staged bilateral TKA was performed using a different randomly selected prosthesis on each knee (Fig. 23.4). Five different prostheses were used: bicruciate (ACL-PCL), medial pivot (MP), posterior stabilized (PS), posterior cruciate retaining (PCL), and mobile bearing (MB). Each procedure was performed using the same technique with only slight variation as needed to accommodate the different implants. Fair and poor results were excluded to provide a valid comparison, and a minimum of 4 years of follow-up was required. There were 551 patients (1102 knees) who met the inclusion criteria [17–19]. The noise patients experienced after their knee replacement was also evaluated [19]. Using a temperature probe, the temperature of the synovial fluid was measured in 50 patients to assess the amount of heat generated by the implant [20].

Range of motion, pain relief, alignment, and stability did not vary by prosthesis type. The bicruciate prosthesis generated the least amount of heat and least noise. The PS knee had the most noise, generated the second highest amount of heat, and was the least preferred knee. The MP was equal to the ACL–PCL as most preferred and had the second fewest noise concerns. Patients gave the following reasons for their knee preference: feels more normal; stronger on stairs; superior single-leg weight bearing; flexion stability; fewer clunks, pops, and clicks; and don't know. Overall, 89% of patients preferred the ACL–PCL knee over the PS, 76% preferred the MP to the PS and PCL, and 61% preferred MP to the MB [17–19, 21].

23.10 Bicruciate Implant Design Features

Successful bicruciate total knee replacement is most dependent on the correct design of the tibial component. The thinnest possible component is desirable, and strength is important, as early tibial implant designs were known to fracture. A supportive keel is placed on the undersurface of the tibial component. Fixation pegs or holes for screws are necessary for firm fixation of the tibia. The reduced contact area of the bicruciate tibial

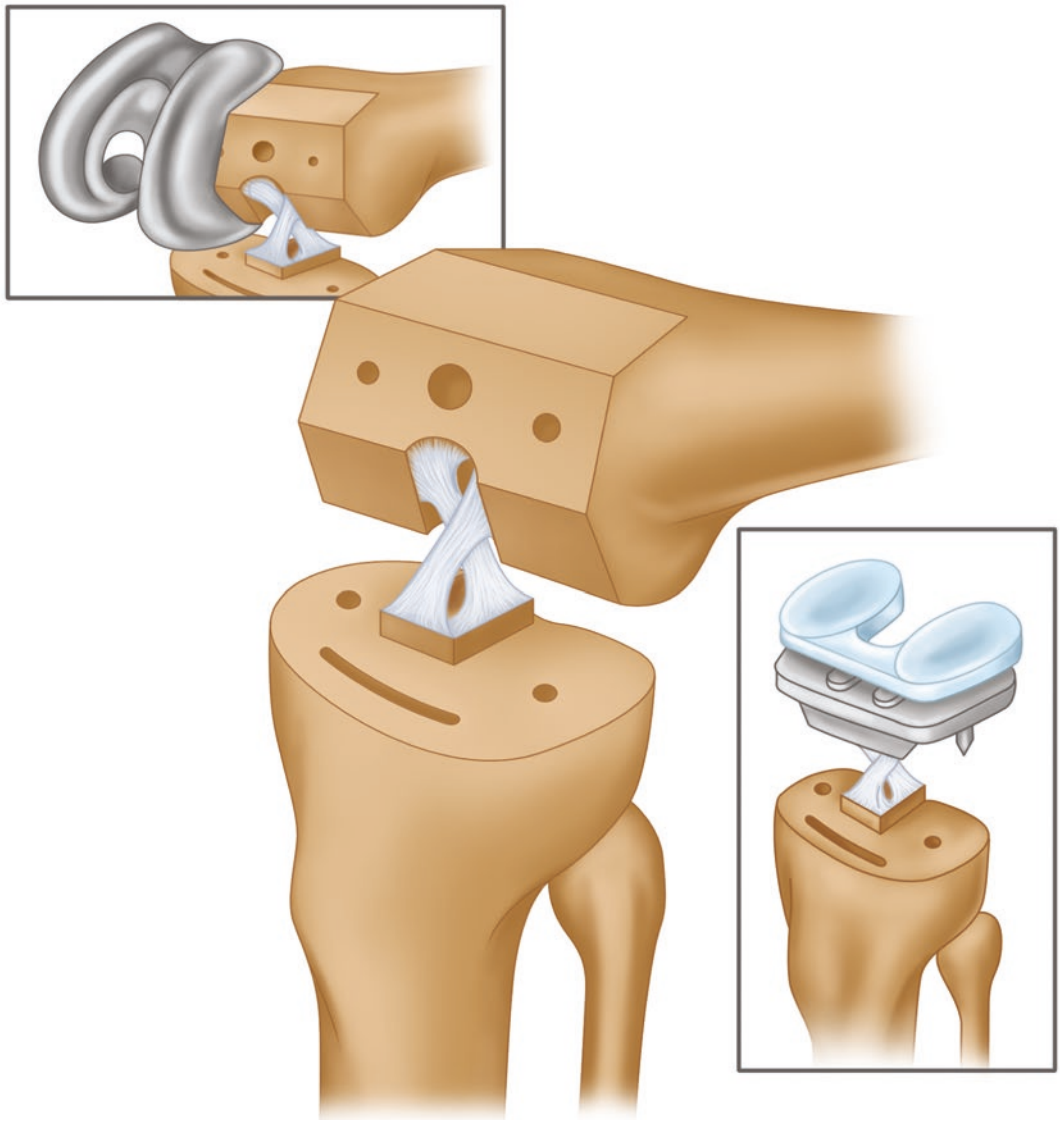

Fig. 23.5 This is a drawing of a Townley bicruciate total knee prosthesis

component to the proximal tibia compared to other total knee designs mandates precise insertion technique. Both cemented and cementless fixations have been used with equal results.

An all-polyethylene tibial implant was used in the 1970s. Metal backing was added to allow for modularity. Wear of conventional polyethylene was a concern, and it was the most common failure mode. Improvements in polyethylene and polyethylene sterilization methods have greatly reduced wear. The shape of the tibial polyethylene component is very important. Flat-shaped tibial polyethylenes were used for many years, but the femoral rollback in the lateral component was insufficient, leading to less flexion than is now desired (Fig. 23.5). A posterior bevel for the lateral tibial polyethylene insert allows much improved rollback and greater knee flexion [22]. There is a slight concavity to the medial tibial insert. The medial and lateral inserts may be 1

or 2 mm different in thickness. The tibial tray is anatomically rather than symmetrically shaped.

The bicruciate femoral component is subtlety distinct from most other posterior cruciate-retaining total knee designs. The radius of curvature of the medial femoral condyle is slightly larger than the lateral. The trochlear groove is anatomically shaped rather than deepened. Right and left femoral components are necessary. The femoral component is available in both cobalt–chromium and oxidized zirconium, and fully ceramic models are being investigated (Fig. 23.3) [23].

Predicate bicruciate knee replacements suffered from design flaws. The BP, Geomedic, and Cloutier were used in the 1970s and 1980s [3, 8, 15]. The femur was multiradius with a nonanatomic trochlea. The tibia was symmetric with symmetric polyethylene inserts. The implants were placed with mechanical alignment which made the ACL and PCL difficult to balance. The future of bicruciate knee replacement may include patient-specific implants, kinematic alignment and precision bone preparation, and ligament balancing.

23.11 Why Do I Recommend Bicruciate Total Knee Replacement?

I recommend bicruciate total knee replacement to patients with intact cruciate ligaments who need the highest functional outcomes. Bicruciate TKA is a demanding procedure to perform; however, it is possible to master the procedure. It is as reproducible as other methods once experience is gained. Not subluxing the knee reduces trauma. It is a benefit not to elevate the joint line and to leave the operating room with all four ligaments with the correct tension. It is also more reliable to depend on the knee's natural kinematic balance for knee stability rather on than the shape of metal and polyethylene.

Patients whose activities require a stable single-leg stance benefit from bicruciate total knee replacement. The recovery from surgery is rapid, and recovery is to a higher level of function. Tibiofemoral instability requiring revision virtually does not occur with bicruciate knee replacement. The patellofemoral joint tracking benefits as well. Patients report a more normal feeling knee; fewer complaints of noise such as clunking, popping, and clicking; better strength and stability on stairs; and better performance in single-leg weight-bearing activities. Most importantly, in paired bilateral studies, patients prefer bicruciate total knee replacement to their other implant choices. As with any TKA, proper patient selection is necessary to assure a successful clinical outcome and a satisfied patient.

Clinical Case

A 49-year-old professional golfer presented after experiencing several years of progressive knee pain. He had been treated with nonsteroidal anti-inflammatory drugs (NSAIDs), an unloader brace, and injections with steroids. He could no longer compete professionally in golf due to his knee pain.

His physical examination showed a flexion contracture with a range of motion of 10°–110°. The motion was stable. There was no forward subluxation of the tibia on the femur with either the anterior drawer or Lachman maneuvers. Radiographic examination showed bone-on-bone contact with a severe varus wear pattern (Fig. 23.6). The patient requested TKA. In golf, balance is critically important. Stability in single-knee weight-bearing flexion is necessary to properly execute a golf shot at the professional level.

The patient elected to undergo a bicruciate total knee replacement, which was performed without complication. The postoperative stability was complete, the range of motion improved to 0°–140°, and the patient was pain free. He returned to professional competition and won a tournament at the highest possible level at age 52. He continues to play golf at age 68. His knee implant remains in place and without any sign of wear or other complications (Fig. 23.6b).

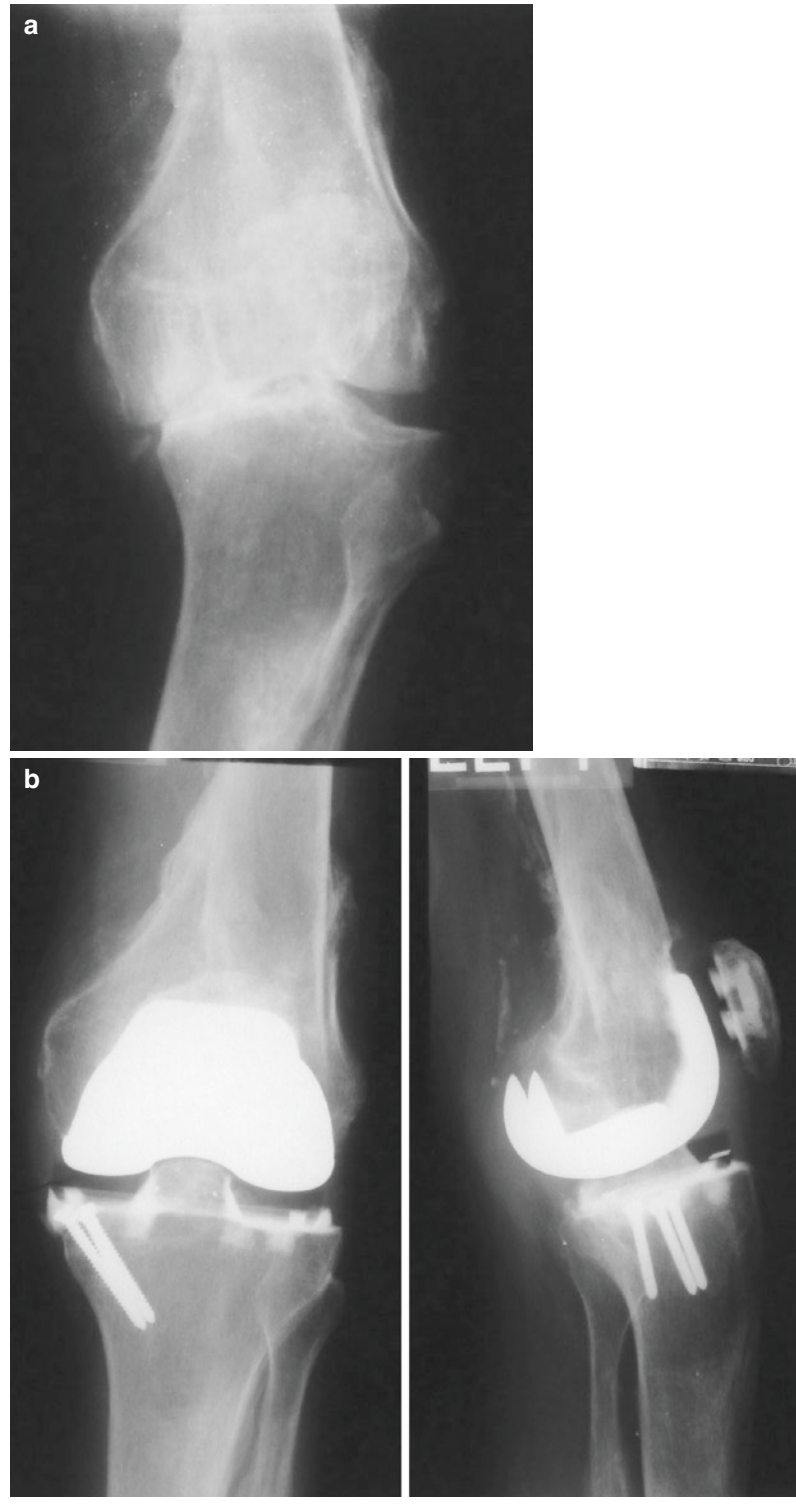

Fig. 23.6 (**a**) The 49-year-old golf professional was seen in 1976 for severe arthritis with a varus deformity. (**b**) The result of his Townley anatomic knee remained good 24 years later

References

1. Cushner FD, La Rosa DF, Vigorita VJ, Scuderi GR, Scott WN, Insall JN. A quantitative histologic comparison: ACL degeneration in the osteoarthritic knee. J Arthroplast. 2003;18:687–92.
2. Townley CO. Articular-plate replacement arthroplasty for the knee joint. 1964. Clin Orthop Relat Res. 1988;236:3–7.
3. Robinson RP. The early innovators of today's resurfacing condylar knees. J Arthroplast. 2005;20(1):2–26.
4. Pritchett JW. Total articular knee replacement using polyurethane. J Knee Surg. 2019;32(3):101–6.
5. Insall JN. Presidential address to the Knee Society. Choices and compromises in total knee arthroplasty. Clin Orthop Relat Res. 1988;226:43–8.
6. Redler I. Polymer osteosynthesis. A clinical trial of Ostamer in forty-two patients. J Bone Joint Surg Am. 1962;44:1621–52.
7. Townley CO. Knee joint arthroplasty: long-term results of the tibial articular replacement plate and its current use in an anatomic total knee arthroplasty. Clin Orthop Relat Res. 1973;94:311–2.
8. Sabouret P, Lavoie F, Cloutier JM. Total knee replacement with retention of both cruciate ligaments: a 22-year follow-up study. Bone Joint J. 2013;95-B:917–22.
9. Fuchs S, Tibescu CO, Genkinger M, Laass H, Rosenbaum D. Proprioception with bicondylar sledge design prostheses retaining cruciate ligaments. Clin Orthop Relat Res. 2003;406:148–54.
10. Komistek RD, Allain J, Anderson DT, Dennis DA, Goutallier D. In vivo kinematics for subjects with and without an anterior cruciate ligament. Clin Orthop Relat Res. 2002;404:315–25.
11. Stiehl JB, Komistek RD, Cloutier JM, Dennis DA. The cruciate ligaments in total knee arthroplasty: a kinematic analysis of 2 total knee arthroplasties. J Arthroplast. 2000;15:545–50.
12. Christensen JC, Brothers J, Stoddard GJ, et al. Higher frequency of reoperation with a new bicruciate-retaining total knee arthroplasty. Clin Orthop Relat Res. 2017;475:62–9.
13. Townley CO. The anatomic total knee resurfacing arthroplasty. Clin Orthop Relat Res. 1985;192:82–96.
14. Townley CO. Total knee arthroplasty. A personal retrospective and prospective review. Clin Orthop Relat Res. 1988;236:8–22.
15. Buechel FF, Pappas MJ. Long-term survivorship analysis of cruciate-sparing versus cruciate-sacrificing knee prostheses using meniscal bearings. Clin Orthop Relat Res. 1990;260:162–9.
16. Pritchett JW. Bicruciate-retaining total knee replacement provides satisfactory function and implant survivorship at 23 years. Clin Orthop Relat Res. 2015;473:2327–33.
17. Pritchett JW. Anterior cruciate-retaining total knee arthroplasty. J Arthroplast. 1996;11:194–7.
18. Pritchett JW. Patient preferences in knee prostheses. J Bone Joint Surg Br. 2004;86:979–82.
19. Pritchett JW. Patients prefer a bicruciate-retaining or the medial pivot total knee prosthesis. J Arthroplast. 2011;26:224–8.
20. Pritchett JW. Heat generated by knee prostheses. Clin Orthop Relat Res. 2006;442:195–8.
21. Pritchett JW. A comparison of the noise generated from different types of knee prostheses. J Knee Surg. 2013;26:101–4.
22. Pinskerova V, Johal P, Nakagawa S, et al. Does the femur roll-back with flexion? J Bone Joint Surg Br. 2004;86:925–31.
23. Tria AJ Jr. A contemporary bicruciate total knee arthroplasty. Semin Arthroplast. 2017;28:65–70.