Unicondylar Osteoarticular Allografts of the Knee

Surgical Technique

By D. Luis Muscolo, MD, Miguel A. Ayerza, MD, Luis A. Aponte-Tinao, MD, Eduardo Abalo, MD, and German Farfalli, MD

Investigation performed at Institute of Orthopedics "Carlos E. Ottolenghi," Italian Hospital of Buenos Aires, Buenos Aires, Argentina

The original scientific article in which the surgical technique was presented was published in JBJS Vol. 89-A, pp. 2137-42, October 2007

ABSTRACT FROM THE ORIGINAL ARTICLE

BACKGROUND: In the management of a resected distal femoral or proximal tibial condyle as the result of tumor or trauma, a unicondylar osteoarticular allograft is currently the only reconstructive option that avoids the sacrifice of the unaffected condyle. The purposes of this study were to perform a survival analysis of unicondylar osteoarticular allografts of the knee and to evaluate the complications.

METHODS: We retrospectively reviewed the results of forty large unicondylar osteoarticular allograft procedures in thirty-eight patients who were followed for a mean of eleven years. Twenty-nine allografts were femoral transplants and included eleven medial and eighteen lateral femoral condyles. Eleven allografts were tibial transplants, including four medial and seven lateral tibial condyles. The procedure was performed after a tumor resection in thirty-six patients and to replace condylar loss after a severe open fracture in the remaining two patients. Complications were analyzed, and allograft survival from the date of implantation to the date of revision or the time of the latest follow-up was determined. Functional and radiographic results were documented according to the Musculoskeletal Tumor Society scoring system at the time of the latest follow-up.

RESULTS: One patient died of tumor-related causes without allograft failure before the two-year follow-up evaluation. The global rate of allograft survival at both five and ten years was 85%, with a mean follow-up of 148 months. In six patients, the allografts were removed at an average of twenty-six months (range, six to forty-eight months) and these were considered failures. All six patients underwent a second allograft procedure including two new unicondylar and four bicondylar reconstructions. The mean radiographic score for the thirty-three surviving allografts evaluated was 89%, with an average functional score of 27 of a possible 30 points.

CONCLUSIONS: Unicondylar osteoarticular allografts of the knee appear to be a reliable alternative for patients in whom reconstruction of massive osteoarticular bone loss is limited to one condyle of the femur or tibia.

LEVEL OF EVIDENCE: Therapeutic Level IV. See Instructions to Authors for a complete description of levels of evidence.

ORIGINAL ABSTRACT CITATION: "Unicondylar Osteoarticular Allografts of the Knee" (2007;89:2137-42).

DISCLOSURE: The authors did not receive any outside funding or grants in support of their research for or preparation of this work. Neither they nor a member of their immediate families received payments or other benefits or a commitment or agreement to provide such benefits from a commercial entity. No commercial entity paid or directed, or agreed to pay or direct, any benefits to any research fund, foundation, division, center, clinical practice, or other charitable or nonprofit organization with which the authors, or a member of their immediate families, are affiliated or associated.

A video supplement to this article has been produced by the *Video Journal of Orthopaedics (VJO)*. This production is included on the bound-in DVD as part of this issue and will also be available in streaming video format at the JBJS website, www.jbjs.org. VJO can be contacted at (805) 962-3410, web site: www.vjortho.com.

INTRODUCTION

Surgical resection is the primary treatment goal in cases of aggressive benign and malignant bone tumors. Such treatment often results in the creation of large osseous defects. Unicondylar osteoarticular defects of the knee are challenging because of the demands of stability and function of this weight-bearing joint. Currently, functional reconstructive options for these defects include structural allograft transplantation, endoprosthetic replacement, and composite reconstruction with use of allografts and metal prostheses[1]. Prosthetic and composite reconstructions require sacrificing the uninvolved condyle and the contralateral side of the joint. Bicondylar osteoarticular allografts[2-7] provide the opportunity to support mechanical loads and to attach host ligaments and muscles to the allografts, but this approach compromises both knee condyles in circumstances in which only one condyle is absent or severely damaged. For these reasons, the use of a unicondylar osteoarticular allograft might be a more acceptable option, but the surgical technique of unicondylar osteoarticular allograft reconstruction is demanding. Nevertheless, preserving the uninvolved condyle may substantially improve the biomechanics of the knee following the reconstruction. In the present report, we describe the technical details of the resection of malignant or aggressive benign bone tumors and the subsequent reconstruction with a unicondylar osteoarticular allograft.

SURGICAL TECHNIQUE

Allograft Selection

Fresh-frozen allografts are obtained and stored according to a

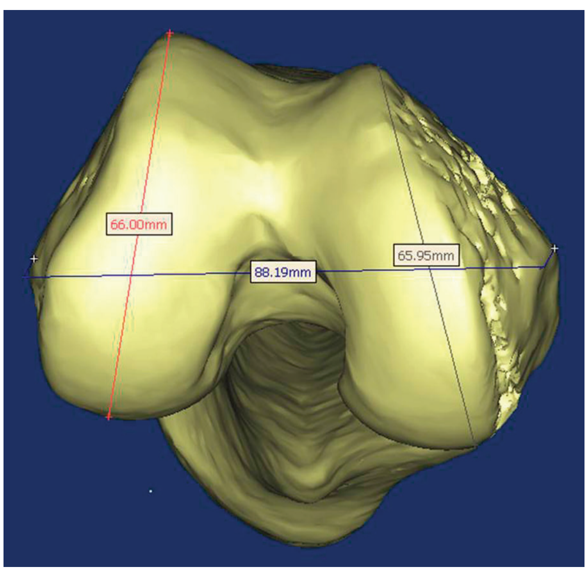


FIG. 1

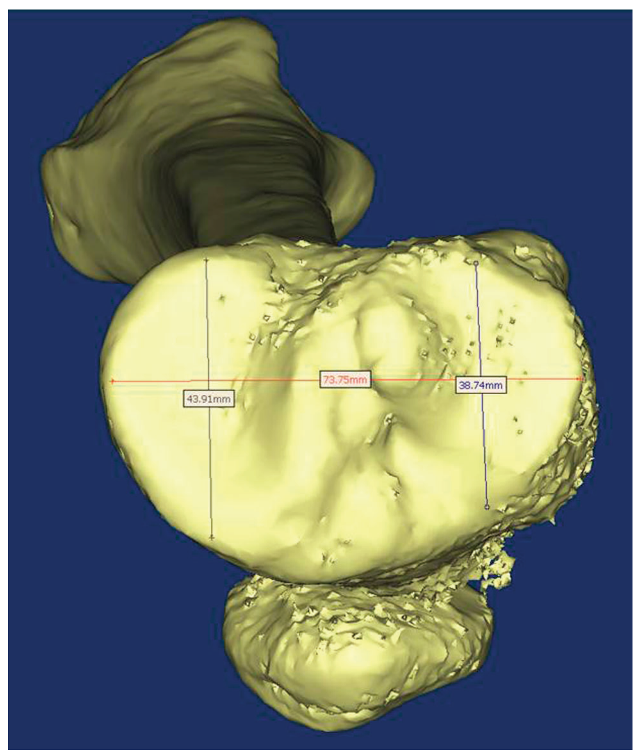


FIG. 2

Fig. 1 Axial view of a three-dimensional reconstruction of a distal femoral allograft, based on computed tomography scans made prior to implantation, demonstrating the maximum total width and anteroposterior dimension of the medial and lateral condyles. **Fig. 2** Axial view of a three-dimensional reconstruction of a proximal tibial allograft, based on computed tomography scans made prior to implantation, demonstrating the maximum total width and the anteroposterior width of the medial and lateral plateaus.

FIG. 3

FIG. 4

Fig. 3 Anteroposterior radiograph of the right knee, showing the giant-cell tumor comprising only the lateral condyle. **Fig. 4** Coronal T2-weighted magnetic resonance image illustrating the preoperative extent of the tumor.

previously described technique[7]. Poor anatomical matching in terms of both size and shape between the host defect and the graft can substantially alter joint kinematics and load distribution, leading to bone resorption or joint degeneration. To improve the accuracy in size matching between the donor and the host, we developed measurable parameters on the basis of computed tomography scans[7]. On the axial view of the distal part of the femur, we determine the maximum total width and anteroposterior dimension of the medial and lateral condyles (Fig. 1) and the width of the intercondylar notch. In the proximal part of the tibia, the maximum total width and the anteroposterior width of the medial and lateral plateaus are measured (Fig. 2). These measurements are available in our hospital bone bank and facilitate selection of the best graft to match the patient. The allograft selection is based on a comparison of these parameters with those of the donor.

Unicondylar Osteoarticular Allograft of the Distal Part of the Femur

Preoperative imaging includes magnetic resonance imaging and computed tomography as necessary to define the margins of the lesion and the intended resection (Figs. 3 and 4). All operations are performed in a clean-air enclosure with vertical airflow and usually with spinal anesthe-

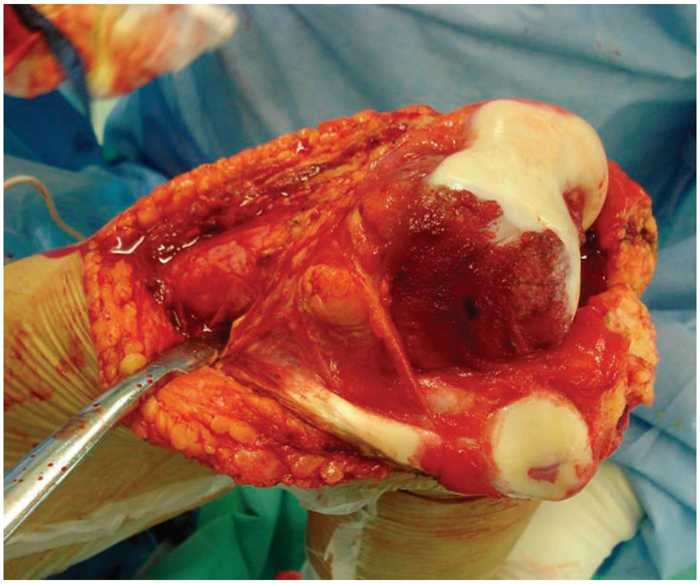


FIG. 5

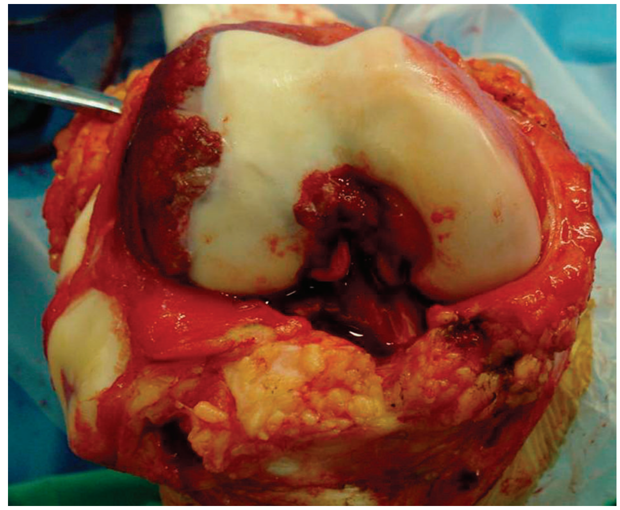


FIG. 6

Fig. 5 Intraoperative photograph showing the wide exposure of the distal part of the femur after the performance of a medial parapatellar arthrotomy. **Fig. 6** Intraoperative photograph showing that the articular cartilage of the lateral condyle is compromised by the tumor.

sia. The patient is placed on the operating table in the supine position. A sandbag is placed under the ipsilateral buttock. A long midline skin incision is made, beginning in the middle part of the thigh, and a medial parapatellar arthrotomy is performed in a manner similar to that of a total

FIG. 7

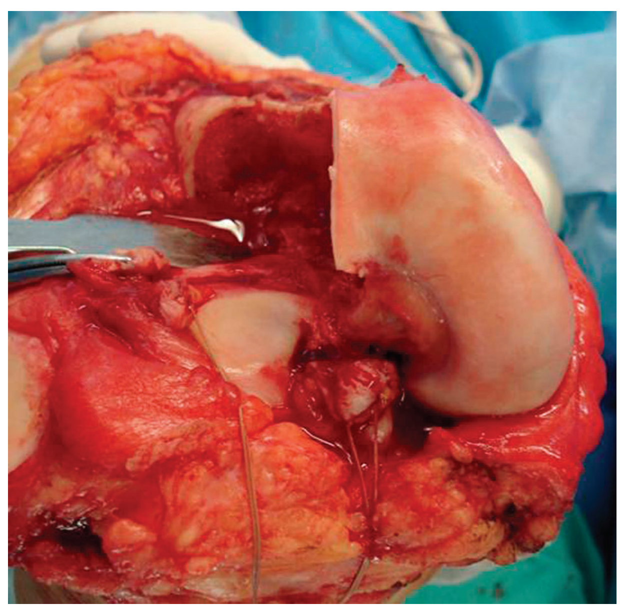


FIG. 8

Fig. 7 Intraoperative photograph of the donor graft, showing a size and shape similar to the recipient bone. **Fig. 8** Intraoperative photograph, made after the lateral condyle had been resected, showing the osteoarticular defect.

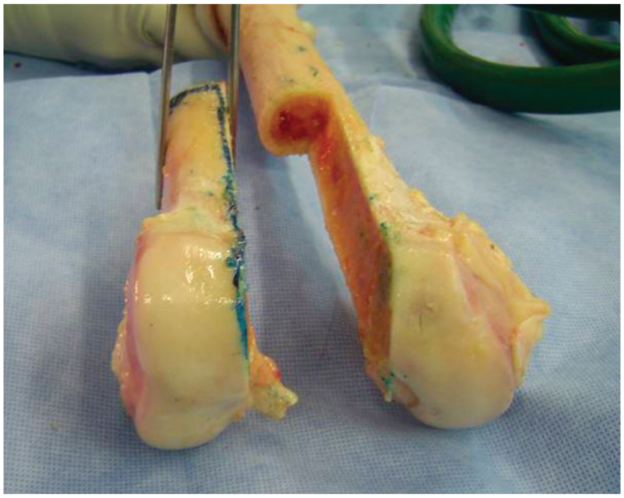
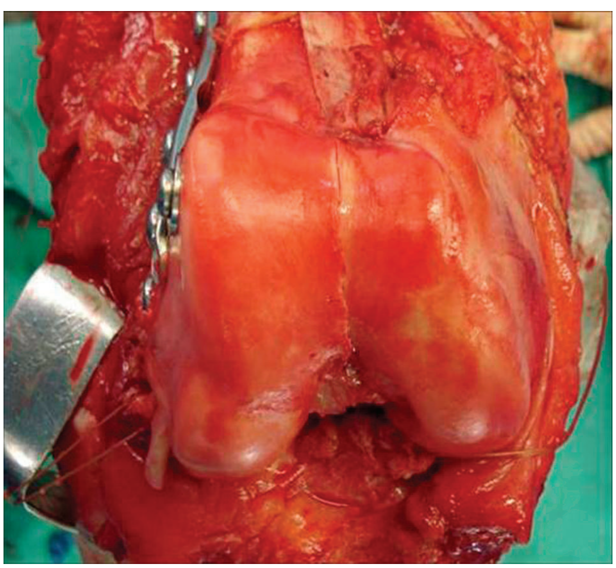


FIG. 9

Intraoperative photograph showing how the distal femoral transplant is appropriately sized on the basis of intraoperative measures.

knee replacement. The distal part of the femur is approached through the interval between the rectus femoris and the vastus medialis. The patella is then everted, and the knee is flexed to expose the joint (Fig. 5). The cruciate and collateral ligaments of the affected condyle (that is, the anterior cruciate and lateral collateral ligaments for the lateral condyle and the posterior cruciate and medial collateral ligaments for the medial condyle) are identified (Figs. 6 and 7) and are sectioned close to their femoral attachments to ensure presentation of sufficient length to allow reattachment to the donor. If there is an extraosseous tumor component, a cuff of normal muscle must also be excised. A femoral osteotomy is performed at the appropriate location on the basis of preoperative imaging studies. The longitudinal limb of the osteotomy is performed parallel to the long axis of the femur, and the transverse limb is performed perpendicular to the axis of the shaft, in order to preserve the unaffected condyle (Fig. 8). Simultaneously with the tumor resection, the al-



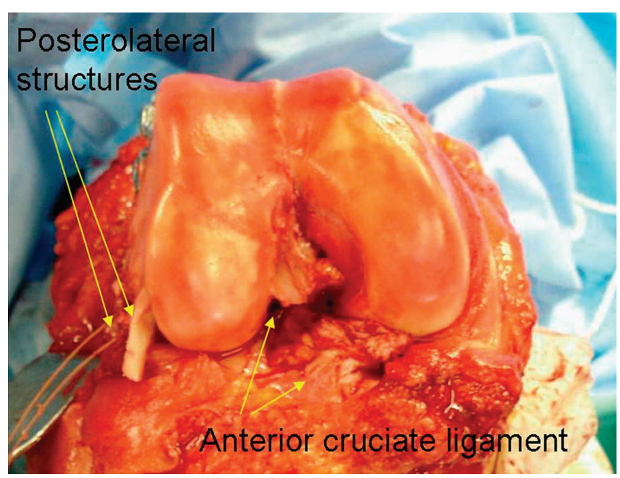


FIG. 10 FIG. 11

Fig. 10 Intraoperative photograph showing the close apposition between the allograft and the host bone, with adequate compression after internal fixation with two cancellous screws and a locking compression plate. **Fig. 11** Intraoperative photograph made after internal fixation of the osteotomy site. The knee is flexed to allow joint reconstruction. Note the posterolateral structures and the anterior cruciate ligament prior to suture.

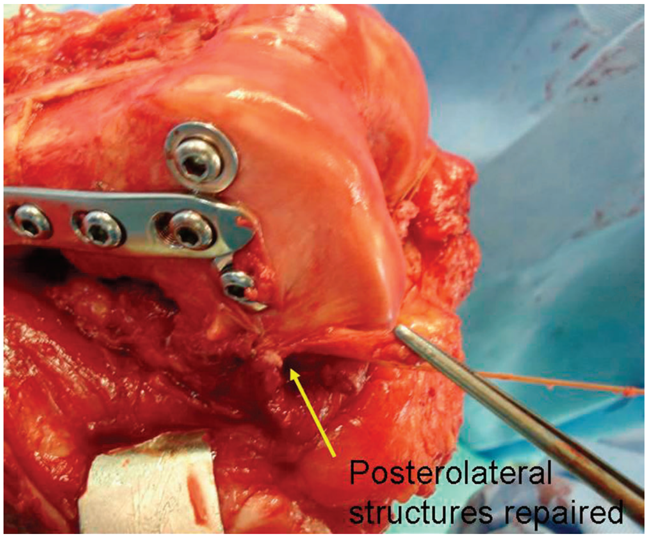


FIG. 12

Intraoperative photograph made after the posterolateral structures of the host have been repaired with the corresponding allograft tissue.

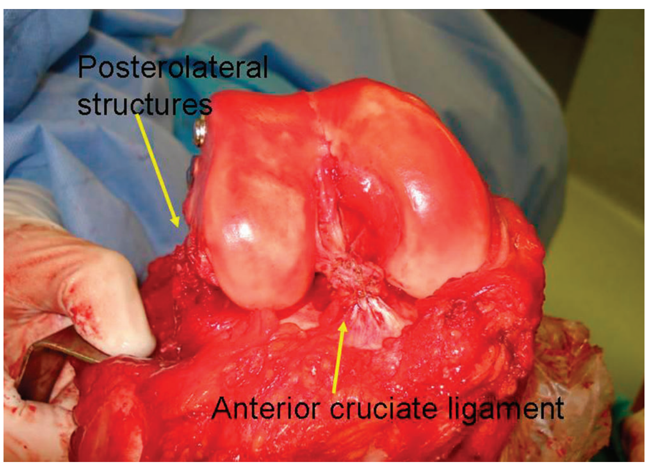


FIG. 13

Intraoperative photograph made after repair of the anterior cruciate ligament.

lograft specimen is prepared on the back table. The graft is taken out of the plastic packaging and is placed directly in warm normal saline solution. After being thawed, the donor bone is cut to the proper dimensions (Fig. 9) and the soft-tissue structures, such as the cruciate and collateral ligaments, are prepared for implantation and reattachment. It is critical that adequate soft-tissue structures remain on the allograft so that they can be sutured to their counterparts on the host. After resection of the tumor, the distal femoral allograft is inspected to confirm the appropriate size and the absence of degenerative changes. The allograft segment is then tailored to fit the bone defect. Precise apposition between the allograft and the host bone is critical. Distal or proximal malpositioning would lead to offset of the articular surface and inappropriate loading of the affected compartment, with a resulting varus or valgus deformity. When a satisfactory reduction has been obtained, the graft is provisionally secured with threaded

FIG. 14

Anteroposterior radiograph made eight months after tumor resection and osteoarticular allografting of the lateral condyle of the femur, showing healing at the metaphyseal osteotomy site with satisfactory joint congruence and alignment.

Kirschner wires that are inserted through the distal part of the condyle. The graft is then stabilized by means of internal fixation with cancellous screws compressing the metaphyseal bone. A plate is applied to fix the diaphyseal osteotomy site; in order to minimize the risk of fracture, it should span as much allograft length as possible (Fig. 10). Once the allograft has been secured to the host bone, the knee is flexed to allow soft-tissue reconstruction of the joint (Fig. 11). We use a number-1 nonabsorbable suture to repair the native cruciate ligament (the anterior cruciate ligament for the lateral condyle and the posterior cruciate ligament for the medial condyle) to the corresponding cruciate tissues provided by the allograft. Finally, the corresponding collateral ligament (the lateral collateral ligament for the lateral condyle and the medial collateral ligament for the medial condyle) is repaired in similar fashion (Figs. 12, 13, and 14). The patella is reduced, if it was not originally detached, by suturing the capsule and parapatellar tendons. Two suction drains are inserted, and, after lavage of the wound with saline solution, the quadriceps is meticulously repaired. A layered closure of the subcutaneous tissues and skin is then performed. Prophylactic antibiotics are given intravenously according to a standard protocol, and anticoagulation therapy is routinely employed.

Unicondylar Osteoarticular Allograft of the Proximal Part of the Tibia

The same basic principles are applied for unicondylar osteoarticular allograft reconstruction of the proximal part of the tibia (Figs. 15 and 16). A long midline incision is made, beginning at the upper pole of the patella. The incision is extended over the tibia, and a medial or lateral parapatellar arthrotomy is performed, depending on which tibial condyle is affected. Such an incision provides a wide exposure of the proximal part of the tibia and the knee joint (Fig. 17).

FIG. 15

FIG. 16

Fig. 15 Anteroposterior radiograph of the left knee that shows the compromise of the lateral plateau due to a giant-cell tumor. **Fig. 16** Preoperative coronal T1-weighted magnetic resonance image that illustrates tumor extension into the bone and soft tissues.

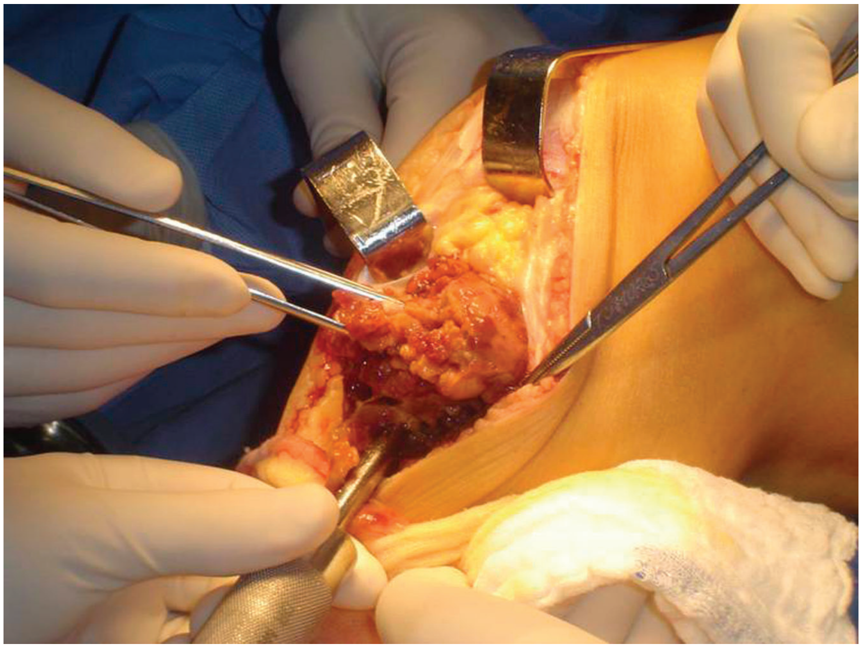


FIG. 17

Intraoperative photograph showing wide exposure of the lateral plateau of the proximal part of the tibia that allows resection of the tumor.

The biopsy track is removed in continuity with the specimen. The proximal part of the tibia is exposed extraperiosteally, and a cuff of normal muscle is excised as a margin around any extraosseous component of the tumor. The osteotomy is planned at the appropriate location as determined on preoperative imaging studies. Both cruciate ligaments and the patellar tendon are identified and are left attached to the unaffected tibial condyle. The meniscus of the affected condyle is detached and is preserved with the host. Regarding the collateral ligaments, only when the medial tibial condyle is involved must the medial collateral ligament be detached, but when the lateral tibial condyle is reconstructed the lateral collateral ligament remains intact with the fibula (Fig. 18). After resection of the tumor, the allograft is tailored to fit into the bone defect (Fig. 19). After the donor bone is thawed in a warm solution, it is cut to the proper dimensions and is inserted into the defect (Figs. 20 and 21). The graft is temporarily secured with threaded Kirschner wires that are placed through the proximal part of the tibial plateau, and the graft is then stabilized by means of internal fixation. A plate is applied across the diaphyseal osteotomy site, and, in order to minimize the risk of fracture, it should span as much allograft length as possible (Fig. 22). Once the allograft bone has been secured to the host, the knee is flexed to allow soft-tissue reconstruction of

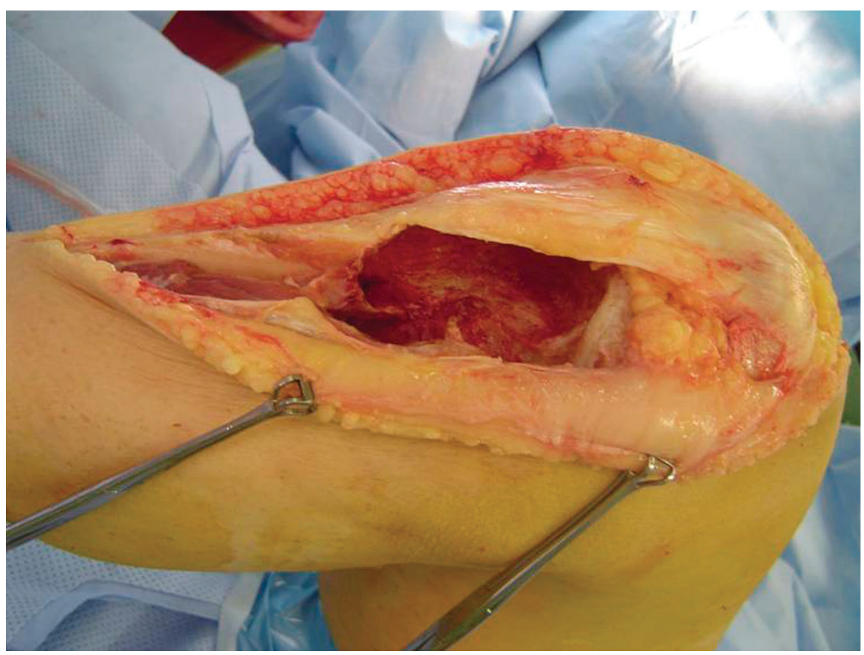


FIG. 18

Intraoperative photograph made after resection of the tumor.

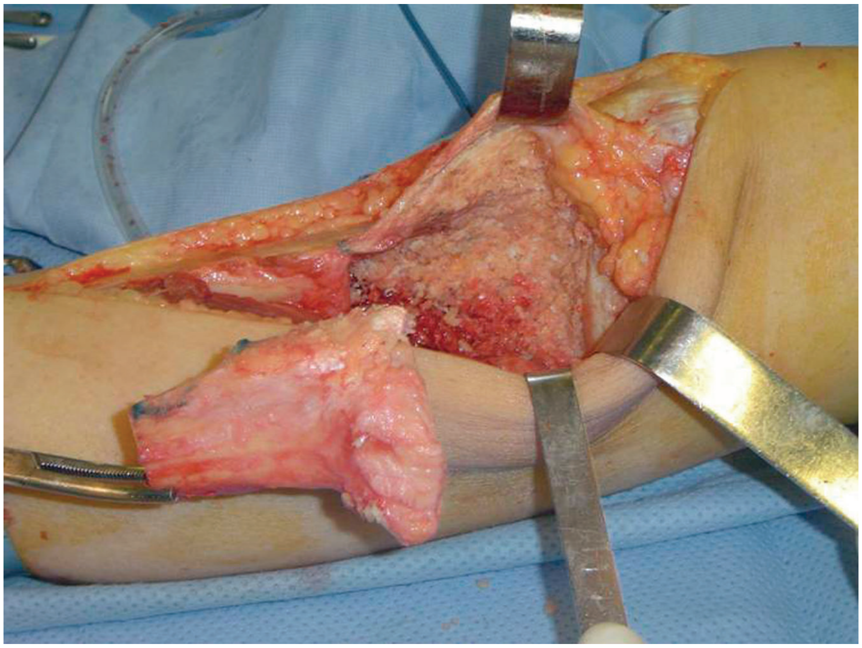


FIG. 19

Intraoperative photograph made after the cavity defect has been filled with morselized bone and before the insertion of the structural allograft.

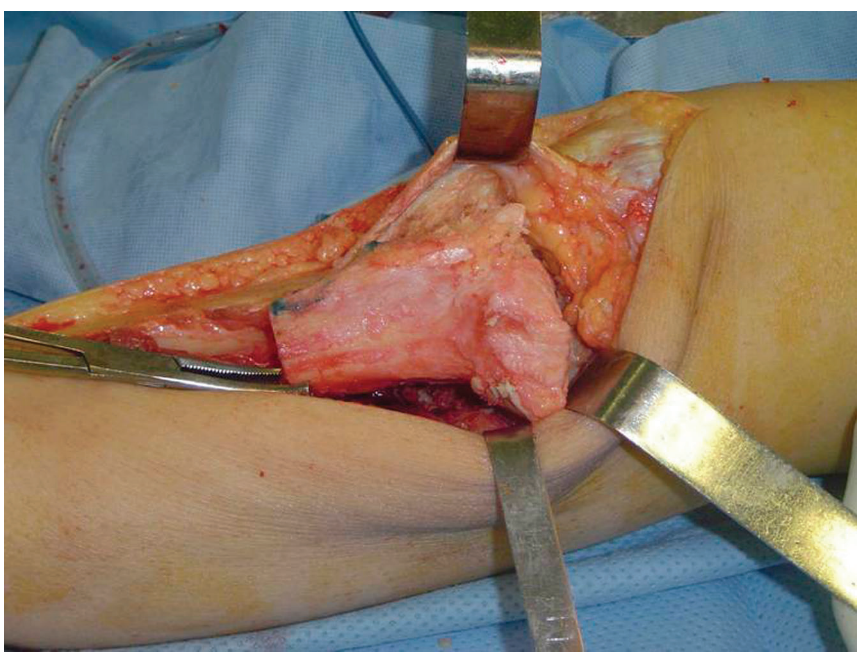


FIG. 20

Intraoperative photograph made after reconstruction with a lateral plateau allograft.

FIG. 21

Intraoperative photograph made with the knee flexed to check joint stability prior to meniscus reinsertion.

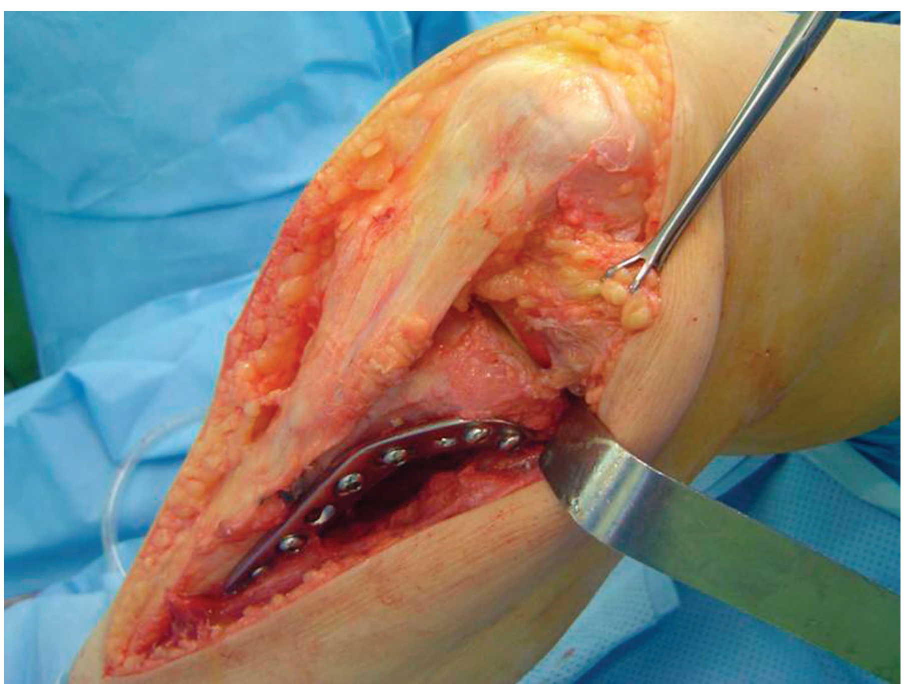


FIG. 22

Intraoperative photograph made after internal fixation has been performed and prior to meniscus reinsertion.

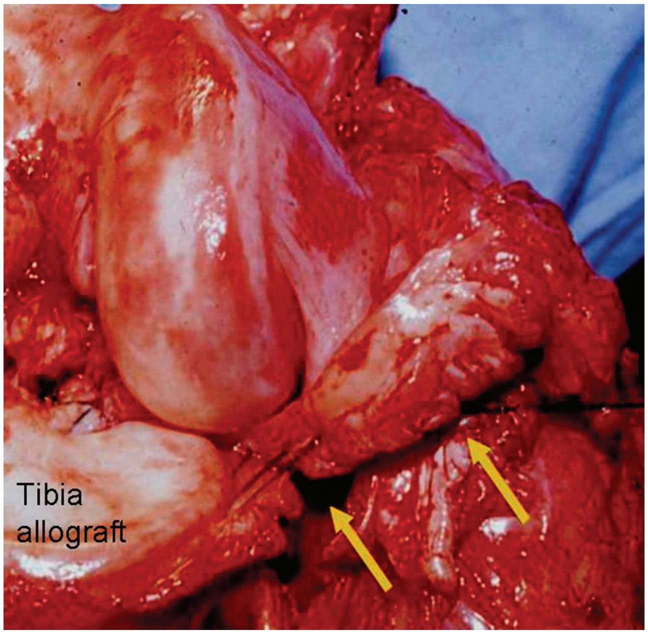


FIG. 23

Intraoperative photograph showing the host meniscus reconstruction to the tibial allograft. The arrows demonstrate how the perimeter of the meniscus is secured to the articular capsule of the allograft.

the joint. The host meniscus is reattached with a number-1 nonabsorbable suture to the osteoarticular allograft by securing the perimeter of the meniscus as well as both the anterior and posterior horns to the articular capsule of the allograft (Fig. 23). In proximal medial tibial unicondylar reconstructions, we use a number-1 nonabsorbable suture to repair the corresponding ends of the medial collateral ligament. Two suction drains are inserted, and, after lavage of the wound with saline solution, a meticulous repair of the quadriceps is completed. A layered closure of the subcutaneous tissues and skin is then performed. Prophylactic antibiotics are given intravenously, and anticoagulation therapy is routinely employed.

AFTERCARE

After reconstruction, the knee is placed in full extension and is secured with a knee immobilizer or a locked hinged postoperative brace. After two days, the drains are removed and the wound is inspected. Ice or a cryotherapy device is used to minimize postoperative swelling and discomfort. Postoperatively, a physical therapist instructs the patient in brace use, crutch walking, and isometric quadriceps exercises. The goals during the first postoperative week are to minimize swelling and to obtain complete passive extension. Passive flexion exercises are instituted during the second postoperative week, with the goal of obtaining at least 60° of flexion. At four weeks postoperatively, active-assisted knee motion is initiated until full active extension and 90° of flexion are obtained. The patient is allowed partial weight-bearing at eight to twelve weeks, and at this time the knee brace is discontinued, depending on the stability obtained at the time of the operation. Increased weight-bearing is permitted according to the progression of radiographic union of the allograft and the host bone (Figs. 14 and 24).

FIG. 24

Anteroposterior radiograph made two years after tumor resection and osteoarticular allografting of the lateral plateau of the proximal part of the tibia, showing healing of the osteotomy site and a satisfactory joint space.

CRITICAL CONCEPTS

INDICATIONS:

- The procedure is appropriate for the treatment of massive unicondylar osteoarticular defects after tumor resection or traumatic bone loss.
- The major neurovascular bundle must be free of tumor.

CONTRAINDICATIONS:

- Tumor affecting both condyles.
- Inadequate host soft tissue to reconstruct the joint.
- Degenerative changes of the tibial or femoral articular surfaces. In this situation, an allograft prosthetic composite is used.

PITFALLS:

- The procedure is best performed by an orthopaedic oncologic surgeon with experience in knee reconstructive and sports-medicine procedures.
- All previous biopsy sites and all potentially contaminated tissues, including any needle biopsy tracks, should be removed en bloc with the surgical specimen.
- Poor anatomical matching for size and shape between the host defect and the graft or proximal-distal malpositioning of the articular surface of the graft will substantially alter joint kinematics and load distribution, leading to bone resorption, joint degeneration, and/or varus or valgus axial malalignment.
- Reconstruction of the ligaments must be meticulous and precise because one side of the joint is normal. Balancing of the soft tissues is critical.
- To obtain a solid allograft construct, the internal fixation should span the entire length of the allograft.

AUTHOR UPDATE:

- Since the original article was published, the surgical approach has remained essentially unchanged.
- A locking compression plate is now used for the majority of our patients because we believe that it imparts greater mechanical stability to the reconstruction.
- The postoperative care and rehabilitation have remained unchanged.

D. Luis Muscolo, MD
Miguel A. Ayerza, MD
Luis A. Aponte-Tinao, MD
Eduardo Abalo, MD
German Farfalli, MD
Institute of Orthopedics "Carlos E. Ottolenghi," Italian Hospital of Buenos Aires, Potosí 4247, 1199, Buenos Aires, Argentina. E-mail address for D.L. Muscolo: luis.muscolo@hospitalitaliano.org.ar

REFERENCES

1. Sim FH, Beauchamp CP, Chao EY. Reconstruction of musculoskeletal defects about the knee for tumor. Clin Orthop Relat Res. 1987;221:188-201.

2. Alho A, Karaharju EO, Korkala O, Laasonen E. Hemijoint allografts in the treatment of low grade malignant and aggressive bone tumours about the knee. Int Orthop. 1987;11:35-41.

3. Hornicek FJ Jr, Mnaymneh W, Lackman RD, Exner GU, Malinin TI. Limb salvage with osteoarticular allografts after resection of proximal tibia bone tumors. Clin Orthop Relat Res. 1998;352:179-86.

4. Mankin HJ, Gebhardt MC, Tomford WW. The use of frozen cadaveric allografts in the management of patients with bone tumors of the extremities. Orthop Clin North Am. 1987;18:275-89.

5. Mnaymneh W, Malinin TI, Lackman RD, Hornicek FJ, Ghandur-Mnaymneh L. Massive distal femoral osteoarticular allografts after resection of bone tumors. Clin Orthop Relat Res. 1994;303:103-15.

6. Muscolo DL, Ayerza MA, Aponte-Tinao LA, Ranalletta M. Use of distal femoral osteoarticular allografts in limb salvage surgery. J Bone Joint Surg Am. 2005;87:2449-55.

7. Muscolo DL, Ayerza MA, Aponte-Tinao LA. Massive allograft use in orthopedic oncology. Orthop Clin North Am. 2006;37:65-74.