Unicondylar Osteoarticular Allografts of the Knee

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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 the tibia.

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

Surgical resection is the primary treatment goal in aggressive benign and malignant bone tumors, often creating 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[2-8] provide the opportunity to support mechanical loads, and attach host ligaments and muscles to the allograft, but this approach compromises both knee condyles in circumstances in which only one condyle is involved by the tumor. For these reasons, unicondylar osteoarticular allografts may be a more acceptable option.

The surgical technique of unicondylar osteoarticular allograft reconstruction is demanding. However, preserving the uninvolved condyle may substantially improve the biomechanics of the reconstruction. The purpose of this study was to analyze the long-term functional and radiographic results of unicondylar osteoarticular allografts of the knee.

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Materials and Methods

Between April 1962 and April 2001, the Orthopaedic Oncology Service at the Italian Hospital of Buenos Aires performed forty unicondylar osteoarticular allograft procedures in thirty-eight patients, among a total of 213 osteoarticular allograft procedures in the same anatomic region. The bone defect was created by the resection of a tumor (thirty-three aggressive or recurrent giant-cell tumors, one high-grade osteosarcoma, one chondrosarcoma, and one malignant fibrous histiocytoma) in thirty-six patients and after a severe open fracture with massive bone and cartilage loss in the remaining two patients. The mean age of the patients was thirty years, with a range of thirteen to fifty-four years. There were eighteen female and twenty male patients, and they were followed for a mean of eleven years (see Appendix).

The decision to implant a unicondylar graft was made on the basis of the aggressiveness of the tumor and the lack of involvement of the condyle as determined by imaging studies. With regard to the malignant tumors in this series, this type of reconstruction was performed when, after an appropriate wide resection, the unaffected condyle remained intact. Benign aggressive tumors, such as giant-cell tumors, were reconstructed with a unicondylar allograft when one condyle had sustained a pathological fracture or when, after the tumor was curetted, there was collapse of the articular surface of one side.

Nonirradiated allografts were harvested under sterile conditions and were stored frozen at –80°C in the bone bank at our institution, according to a technique that has been previously described[6]. No attempt was made to preserve the viability of the articular cartilage, and bacteriological and viral studies were performed in accordance with the recommendations of the American Association of Tissue Banks and with use of the tests available at the time. Thirty-eight transplants were primary procedures, and two were secondary procedures (after two failures of an earlier transplant). The allografts were selected on the basis of a comparison of age, sex, height, and radiographs of the patient with data available from the donor in order to achieve the closest possible anatomical match. Grafts were taken out of the package and placed directly in warm (18° to 22°C) saline solution. After being thawed, the donor bone was cut to the proper size and soft-tissue structures, such as the cruciate ligaments, collateral ligaments, and posterior capsule, were prepared for implantation (Fig. 1).

Twenty-nine allografts were femoral transplants, including eleven medial and eighteen lateral condyles (Fig. 2), and eleven were tibial transplants, including four medial and seven lateral tibial condyles (Fig. 3). Depending upon the condyle reconstructed, the ligaments were reattached to the corresponding allograft tissues to improve stability. Reattachment of the allograft tissue to the host tissue was performed through a direct lateral-lateral continuous suture. In tibial allografts, the host meniscus was reattached to the osteoarticular allograft by suturing the insertions of both horns and the joint capsule. In none of these tibial osteoarticular allografts was the extensor mechanism reconstructed since, in all cases, the tibial tuberosity was preserved. Twenty-eight allografts were fixed with plates and screws, while twelve were stabilized only with screws. Antibiotics were given intravenously until drains were removed on the third postoperative day, and no routine anticoagulation therapy was used. In recent years, external splinting was used until the wound healed. Passive range-of-motion exercises were started two weeks after the operation, depending on the type of soft-tissue reconstruction stability obtained at the time of surgery. Partial weight-bearing was started three months after surgery and, once healing of the osteotomies had been achieved, full weight-bearing was allowed.

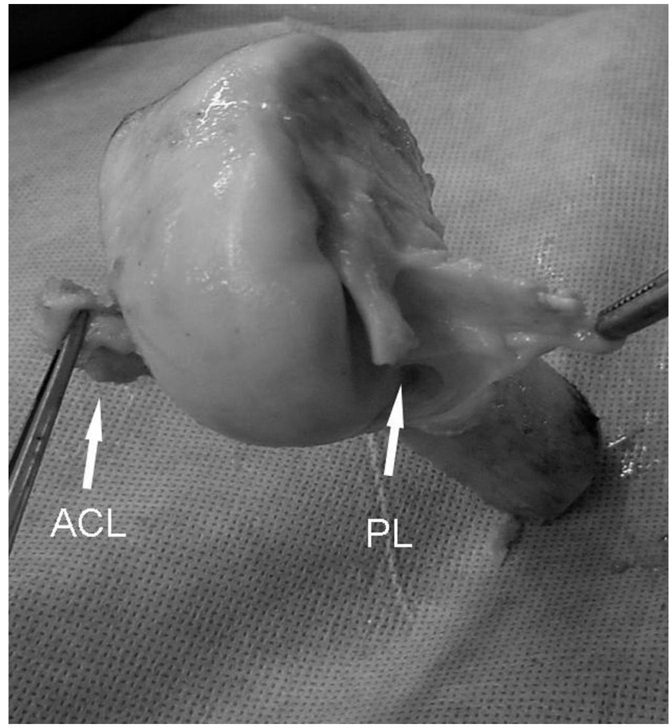

Fig. 1

Intraoperative photograph of a lateral condyle donor graft after having been thawed and cut to the proper size, showing the anterior cruciate ligament (ACL) and posterolateral (PL) structures for joint reconstruction.

Patients were seen postoperatively at one week, two weeks, one month, two months, and three months; every three months thereafter until two years; and then annually. Plain radiographs were made at every visit, beginning one month after the operation.

The functional evaluation of the patients was performed with the use of the revised 30-point functional classification system established by the International Symposium on Limb Salvage and the Musculoskeletal Tumor Society[9]. This functional score measures six parameters: pain, function, emotional acceptance, use of walking supports, walking ability, and gait. Each parameter is given a value ranging from 0 to 5, according to specific criteria. The individual scores are added together to obtain an overall functional score, with a maximum of 30 points. A score of 23 points is considered to be an excellent functional result; between 15 and 22 points, a good result; between 8 and 14 points, a fair result; and <8 points, a poor

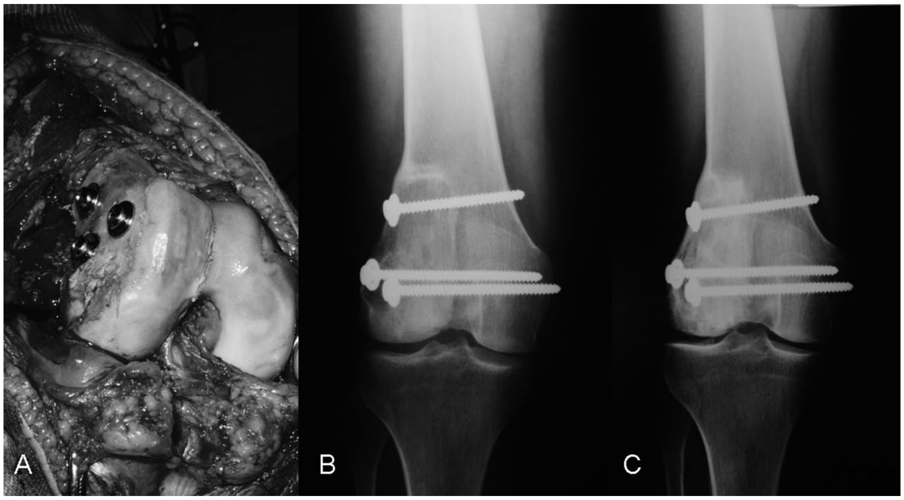

Fig. 2

Case 11, a twenty-one-year-old woman with a diagnosis of giant-cell tumor, who was managed with an osteoarticular lateral condylar allograft after tumor resection. *A:* Intraoperative photograph after resection of the tumor and allograft placement showing the congruency between the lateral condyle and the host medial condyle with adequate joint matching. *B:* Anteroposterior radiograph made two years after implantation of the unicondylar osteoarticular allograft. *C:* Radiograph made at the eighteen-year follow-up evaluation shows an adequate articular space and full incorporation of the graft.

result. The clinical study was approved by the institutional review board. Orthopaedic surgeons (L.A.A.T. and E.A.) interviewed patients by telephone or at their latest follow-up evaluation and completed a questionnaire with each patient.

The result was evaluated with use of plain anteroposterior and intercondylar knee radiographs according to the system proposed by the Musculoskeletal Tumor Society[10], which is based on eight criteria: the healing of proximal or distal osteotomies, the contour of the graft, the fixation of the graft, the density of the graft, the stability of the joint, the diameter of the graft, and the degeneration of the joint. Each parameter is given a value ranging from 0 to 5, according to specific

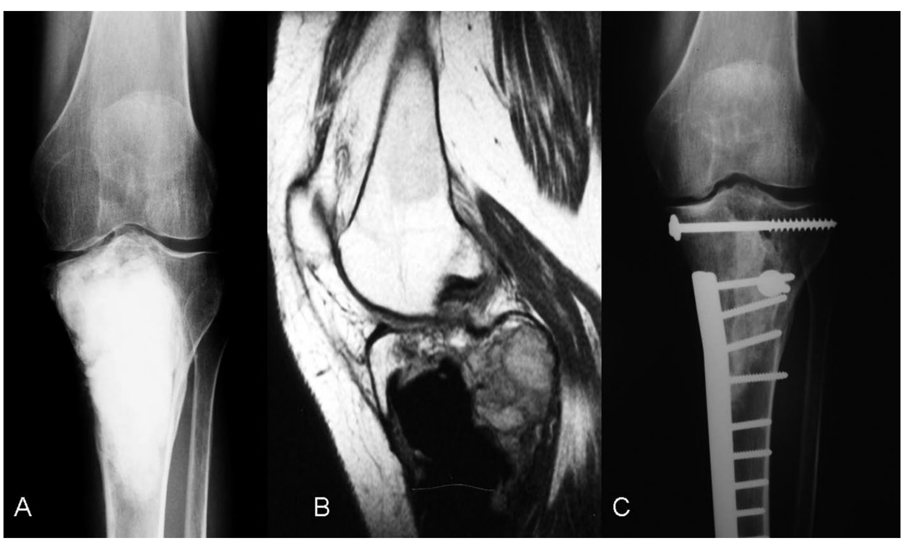

Fig. 3

Case 35, a forty-six-year-old woman with a diagnosis of recurrent giant-cell tumor of the proximal part of the tibia who was managed with an osteoarticular medial unicondylar allograft after tumor resection. *A:* Anteroposterior radiograph of the knee showing collapse of the medial tibial plateau because of a local recurrence of the giant-cell tumor. *B:* Sagittal T1-weighted magnetic resonance image showing the extent of the recurrent giant-cell tumor in the tibia around the cement that was used in the previous surgery. *C:* Anteroposterior radiograph made seven years after surgery showing the unicondylar reconstruction of the medial side of the tibia with solid incorporation of the graft.

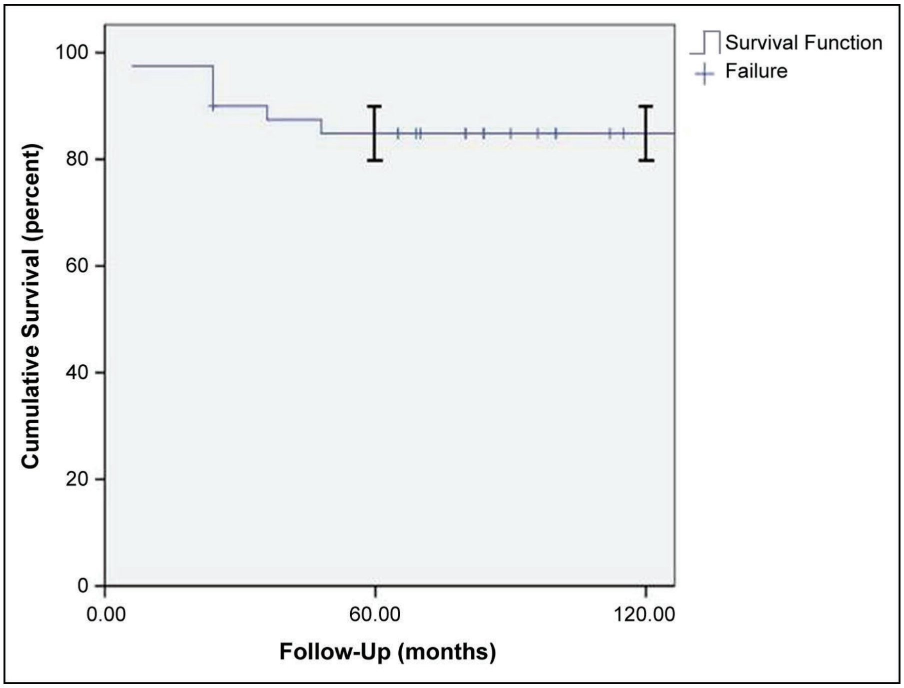

Fig. 4

Kaplan-Meier survivorship curve for the allografts. The I-bars indicate the 95% confidence intervals.

criteria. The score was calculated by adding the value for each criterion and dividing it by the total maximum attainable score. The score is expressed as a percentage, with the maximum possible score being 100%. A percentage of ≥75% is considered an excellent radiographic result; between 50% and 74%, a good result; between 25% and 50%, a fair result; and <25%, a poor result. Two orthopaedic surgeons (L.A.A.T. and G.F.) evaluated the latest follow-up radiographs and completed a form for each patient.

The procedure was considered an allograft failure when the allograft was removed either as a revision procedure or by amputation. The survival of the allograft was estimated with the use of the Kaplan-Meier method[11], starting on the date of the operation and ending on the date of removal or the latest follow-up. Complications, such as local recurrence, fracture, articular collapse, and infection, were analyzed. Cox regression analysis was done to determine whether age, gender, date of surgery, diagnosis, side (medial or lateral), bone (femur or tibia), or type of internal fixation were independent factors related to the survival of the allograft or damage to the joint. The chi-square test was used to compare the overall survival or joint damage among the groups. A p value of <0.05 was considered to be significant.

Results

One patient died of tumor-related causes without allograft failure before the two-year radiographic follow-up evaluation. Among the remaining thirty-nine allografts, six failed at an average of twenty-six months (range, six to forty-eight months) because of infection (two), local recurrence (two), fracture (one), and massive resorption (one).

The two infected grafts were treated with allograft resection, and the defect was maintained by an antibiotic-impregnated polymethylmethacrylate spacer. According to the microorganisms recovered from the site of the infected allograft, antibiotics were administered for one to three months. After achieving infection control, one patient underwent a second unicondylar osteoarticular allograft and the other, a bicondylar osteoarticular allograft.

The two patients with a local tumor recurrence were managed with a bicondylar osteoarticular retransplant. In the patient with an intra-articular allograft fracture, the allograft was removed and a second unicondylar osteoarticular allograft was implanted. This second allograft failed because of massive resorption and was converted to a bicondylar osteoarticular allograft.

Thirty-three unicondylar allografts were in place at the time of the latest follow-up, with an average functional score of 27 points (range, 20 to 30 points). Function was rated as excellent in thirty patients and good in three. Eighteen patients had no pain in the involved knee, and fifteen had modest pain. Fourteen patients had no functional restrictions, eighteen had restrictions in recreational activities, and one had partial disability. Thirty patients were enthusiastic about the result, and three were satisfied. Thirty-two patients walked without the use of supports, and one wore a knee brace. Nineteen patients could walk an unlimited distance, and fourteen had some limitations in walking. Twenty-eight patients had no discernible limp, and five had a minor limp.

Physical examination revealed that the arc of active motion of the knee was a mean of 115° (range, 50° to 135°). The mean radiographic score for the thirty-three allografts evaluated was 89%, which represents an excellent radiographic result, with twenty-seven grafts having scores between 80% and 100%. According to the Musculoskeletal Tumor Society radiographic evaluation, the joint space was rated as unchanged or with minor deterioration in 61% (twenty) of the thirty-three allografts. However, 39% (thirteen) of the thirty-three allografts had some articular deterioration; 18% (six) had joint narrowing of 2 mm, 9% (three) had joint narrowing of 4 mm, and 12% (four) had some form of subchondral bone collapse. Although four patients had severe joint deterioration originating from anatomical mismatches or joint instability, knee prosthetic resurfacing was required in only two patients. With the numbers available, no evidence of a significant relationship was found between articular deterioration and age ($p = 0.68$), gender ($p = 0.16$), date of surgery ($p = 0.85$), diagnosis ($p = 0.19$), side ($p = 0.84$), bone ($p = 0.35$), or type of internal fixation ($p = 0.53$).

At the time of the latest evaluation, thirty-three of the forty allografts remained in place (six had failed and one patient had died) and had been followed for a mean of 148 months (range, sixty-five to 250 months). The Kaplan-Meier survival rate for the osteoarticular allografts was 85% (95% confidence interval, 74% to 96%) at five and ten years (Fig. 4). With the numbers studied, no evidence of a significant relationship was found between the overall allograft survival rate and patient age ($p = 0.61$), gender ($p = 0.77$), date of surgery ($p = 0.97$), diagnosis ($p = 0.78$), side ($p = 0.75$), bone ($p = 0.56$), or type of internal fixation ($p = 0.47$).

Discussion

The primary objective in oncologic surgery is local tumor control, and, after adequate resection, the surgeon must decide which reconstructive procedure is best suited for the patient. It is important to consider the availability of each procedure, the level of surgical difficulty, the morbidity and incidence of complications associated with each option, as well as the prognosis for survival and the potential durability of each.

Large bone defects around the knee can be managed with prosthetic reconstruction with the advantage of maintaining motion and immediate functional restoration[12-20]. However, although high survival rates have recently been reported with this type of reconstruction[12,17], complication and failure rates have also been high in other series[13,16,19,20]. In addition, multiple revisions imply demanding operations with more loss of bone stock. Another main disadvantage is that when the massive osteoarticular bone loss is limited to one condyle, prosthetic reconstruction sacrifices the contralateral articular surface and the unaffected condyle, leading to excessive bone loss. An increased emphasis has been placed on biologic reconstructive alternatives because of concerns related to the durability of prosthetic materials in these generally very young patients. Osteoarticular allografts are readily available from tissue banks and can be matched to the size of the resected bone. For these reasons, unicondylar osteoarticular allografts might be a more acceptable option, with survival rates of 85% at five and ten years and an average functional score of 27 points as shown in this study. Although complications and failures occurred during the first four years, similar to the findings in previous reports for bicondylar allografts[21-23], no additional failures, according to our definition, were found after that period of time.

Late osteoarticular allograft failures may occur over time because of gradual joint deterioration. Anatomical and dimensional matching of the articular surface, obtaining adequate joint stability by host-donor soft-tissue repair, and achieving joint alignment have been associated with minor degenerative changes of the articular surface of osteoarticular allografts[24,25]. Therefore, selection of the closest anatomical match between the host and the donor is crucial. In two of our thirty-three patients, prosthetic knee resurfacing was required because of joint deterioration that originated from anatomical mismatches or joint instability. Additionally, improper surgical placement of the graft could adversely affect the outcome even if an ideal unicondylar graft has been selected. Distal or proximal malposition offset can lead to inappropriate loading of the articular surface, with a consequent varus or valgus deformity of the joint. Appropriate reconstruction of the soft tissues is also an important factor for obtaining joint stability after graft placement. When a bicondylar allograft replacement is used, stability may be controlled by tightening or releasing all newly sutured soft-tissue structures. However, when a unicondylar reconstruction is performed, balancing ligament stability is more demanding since the ligament of the unaffected side of the knee remains intact.

Our study has several limitations. This was a retrospective clinical study with potentially uncontrolled variables, such as different locations (medial and lateral), variable extents of soft-tissue resection, and differences in internal fixation. Other limitations include the small numbers of patients with particular types of replacements (for example, there were only four medial tibial condylar allografts), the inclusion of some patients with only five years of follow-up, and the lack of any control group with bicondylar or prosthetic replacements for comparison. Unicondylar osteoarticular allografts are mainly used following resection of a benign aggressive tumor (such as giant-cell tumor) around the knee or a malignant tumor with growth limited to one condyle and with clearly defined margins. Although this situation is common in orthopaedic oncology, there are few options to reconstruct such a bone defect without compromising the unaffected condyle.

At the present time, there are very limited reconstructive functional options for a severe condylar defect in the knee. The allograft survival rate of 85% at five and ten years in these patients, who were followed for a mean of 148 months, suggests that a unicondylar allograft may be a reliable alternative when the massive osteoarticular bone loss to be reconstructed is limited to one condyle of the knee.

Appendix

eA A table showing the clinical details of all study subjects is available with the electronic versions of this article, on our web site at jbjs.org (go to the article citation and click on

"Supplementary Material") and on our quarterly CD-ROM (call our subscription department, at 781-449-9780, to order the CD-ROM). ■

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