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Allograft osteoarticular resurfacing

Strategy

Osteochondral allograft transplantation is a surgical technique that relies on obtaining tissue from cadaveric "living" donors. The objective is to procure healthy articular cartilage from a donor and transfer it to the damaged area of the recipient's knee. Using cadaveric tissue eliminates the donor site morbidity associated with osteochondral autografting and allows for the treatment of larger and more aggressive lesions in virtually any joint. The technique also allows for the ability to implant fully formed articular cartilage without specific limitation with respect to defect size, and it can be completed as a single-stage procedure. Issues regarding cost, graft availability, cell viability, immunogenicity, and risk of disease transmission are some of the factors that may limit the use of this technique.

The ideal patient for an osteochondral allograft is a younger patient with an isolated traumatic lesion or osteochondritis dissecans (OCD). The lesions should be at least 2–3 cm^2 and can have associated bone loss or compromise due to dysvascular changes (i.e., avascular necrosis, AVN). This technique may be used for larger defects – 3 cm^2 up to an entire hemicondyle. These grafts are most commonly used for the femoral condyle but may also be used for patella, trochlea, and tibial plateau lesions. Because the allograft contains bone, any disorder with associated bone loss (AVN, osteochondral fracture, OCD) may also be restored with this surgical technique. Prior to surgery, all patients should be evaluated for relevant comorbidities such as malalignment, ligamentous instability, and meniscal deficiency.

Availability of graft tissue varies by institution and geographic location. Most transplanted grafts are considered "fresh tissue grafts" meaning that they are procured within 24–48 h of the donor's death, processed and serologically screened within 14 days of procurement, and transplanted within 28 days without the need for deep-frozen storage. Frozen grafts can be stored and shipped on demand, potentially alleviating scheduling issues, but these grafts lack cell viability. Prolonged cold storage method increases the "shelf-life" of the graft to at least 28 days and alleviates scheduling difficulties while maintaining cell viability, but chondrocyte suppression continues to be an issue. Overall, fresh osteochondral tissue demonstrates greater than 60% donor chondrocyte viability at biopsy (1–3).

Incorporation and healing of the allograft depends on creeping substitution of host bone to allograft bone, although the bone may also undergo some degree of necrosis and fail to definitively incorporate (4,5). The main source of graft immunogenicity is the blood or bone marrow elements within the subchondral bone of the donor tissue. At the time of procurement, these elements are pulse-lavaged from the donor tissue to minimize the chance of immune reaction. Even though immune reaction may occur, they are self-limited and do not limit graft success (6). In order to decrease the risk of disease transmission, tissue banks must adhere to strict protocols of donor screening, sterile processing, and serological testing. When a size- and side-matched graft becomes available, the patient is notified and expeditiously scheduled for surgery.

Patient selection

Indications

- Localized, grade III and IV unipolar lesion of the femoral condyle, trochlea, or patella
- Defects due to trauma, OCD, AVN, or intra-articular tibial plateau fractures
- Young, high demand patients who are not candidates for joint replacement
- Moderate-to-large cartilage lesions 15–35 mm in diameter
- Pain and symptoms localized and due to the damaged region

Relative contraindications

- Body mass index >30 kg/m^2
- Age greater than 50 years

– Bipolar lesions
– Uncorrected malalignment, ligament insufficiency, or meniscus deficiency

Absolute contraindications

– Rheumatoid or osteoarthritis and corticosteroid-induced osteonecrosis
– Tumor or infection
– Medical conditions that may affect incorporation of allograft tissue (i.e., insulin-dependent diabetes mellitus)
– Unwillingness or inability to follow rehabilitation regimen

Preoperative evaluation generally includes comprehensive history, physical exam, radiographs, magnetic resonance imaging (MRI), and diagnostic arthroscopy. Historical information should include prior injuries and mechanism of injury, symptom onset, and previous surgical intervention. Acute injuries may present with mechanical symptoms or potentially a loose body, while chronic cartilage damage may result in activity-related swelling, pain, and mechanical symptoms (locking or catching). Range of motion is generally preserved in patients with focal defects; however, gait alterations are possible to reduce loading across the defect (toeing-in or toeing-out). Depending on the location of the lesion, palpation may reveal joint line or peripatellar tenderness. A radiographic series should include long-axis weight bearing, 45° posterior to anterior flexion weight bearing, lateral non-weight bearing, and patellofemoral (sunrise) views with sizing markers (Fig. 1A). All compartments should be evaluated for joint-space narrowing, osteophyte formation, and subchondral changes (sclerosis or cysts). Long axis radiographs are useful for assessing alignment and Q-angle to establish the need for concurrent osteotomy. Anteroposterior and lateral films with markers are utilized to determine the appropriate medial-lateral and anterior-posterior dimensions of the donor graft. MRI functions to evaluate the overall status of the knee (i.e., meniscal or ligament pathology). Fat-suppressed sequences are useful in detecting bone injury – sclerosis, cysts, or edema (Fig. 1B). Subchondral involvement could help preclude the use of other modalities such as autologous chondrocyte implantation.

Surgical technique

The patient is placed in the supine position and anesthetized via general endotracheal, epidural, spinal, or regional anesthesia. A proximal thigh tourniquet is applied prior to prepping and drap-

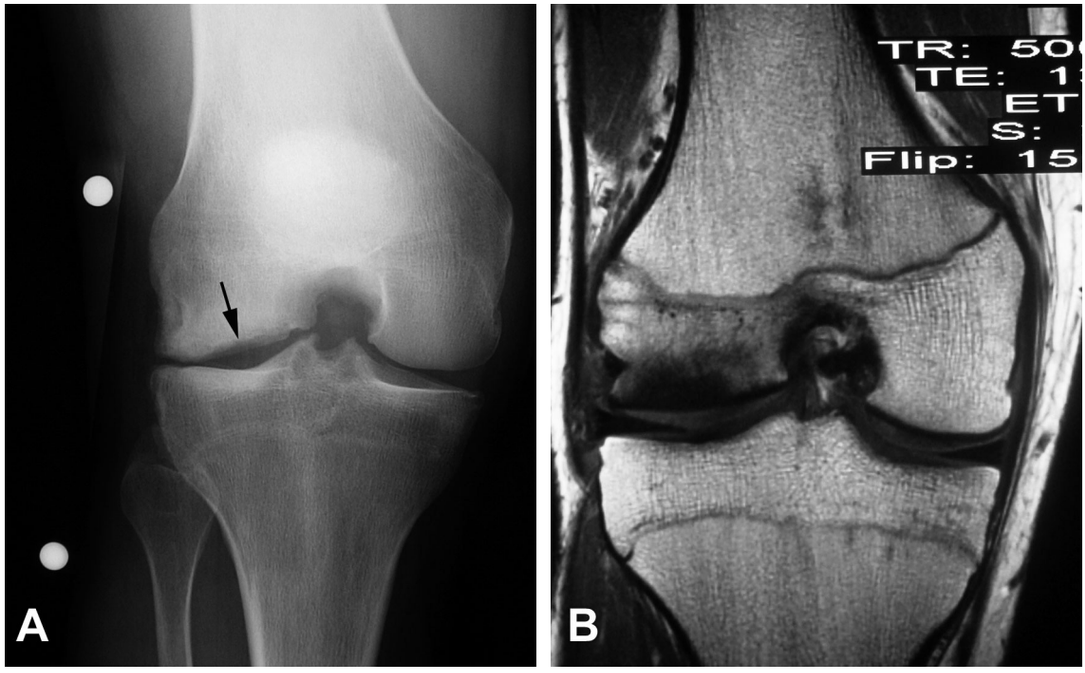

Fig. 1 – Imaging prior to osteochondral allografting. (A) Right knee A-P radiograph for sizing with a 10 cm opaque marker to correct for magnification. The osteochondral lesion has disrupted the normal contour of the lateral femoral condyle (arrow). (B) Coronal T1 image of demonstrating an area of decreased signal intensity in the subchondral bone of the lateral femoral condyle.

ing for a standard knee arthrotomy. The leg is exsanguinated and the tourniquet inflated to maintain hemostasis during the procedure. The articular lesion is exposed through a medial or lateral parapatellar mini-arthrotomy, depending on the location of the lesion (Fig. 2A). The diameter of the defect is assessed using a cannulated sizing cylinder from a commercially available instrumentation system (Arthrex Inc., Naples, FL). The cylinder is centered over the lesion and oriented perpendicular to the cartilage surface. A guide pin is drilled perpendicularly through the center of the lesion to a depth of 2–3 cm. A cannulated reamer is used to excavate the lesion to a depth of 6–8 mm. Adequate fixation is achieved at this depth while minimizing the amount of donor subchondral bone – the most immunogenic component of the graft. The guide pin is removed and the 12 o'clock position is marked on margin of recipient socket. The edges of the socket are debrided to a sharp, clean edge using a no. 15 scalpel blade. To facilitate graft incorporation, vascular channels are created in the base of the lesion by drilling multiple small holes using a small drill bit or Kirshner wire (Fig. 2B). The depth of the recipient socket is assessed in all four quadrants to customize the graft fit.

The donor osteochondral allograft plug is harvested from a full femoral hemicondyle. If the hemicondyle is provided en bloc, it is first trimmed with a power saw to fit securely into the allograft workstation (Fig. 3). The curvature of the harvest site is matched to the curvature of the patient's recipient socket using topographic markings. The 12 o'clock position of the graft is marked and the bushing of the corresponding size is secured over the graft to match the location and size of the recipient socket. The graft is drilled perpendicularly throughout the entire thickness of the hemicondyle while using cold irrigation solution and carefully extracted to avoid

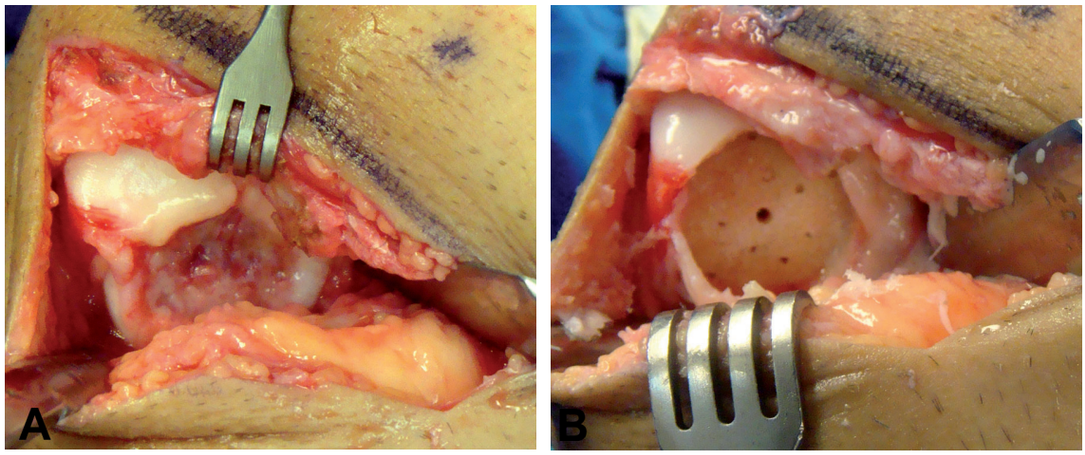

Fig. 2 – (A) An Outerbridge grade IV lesion of the lateral femoral condyle. Note the full thickness loss of cartilage and subchondral bone exposure. (B) Prepared recipient socket of 25 mm in diameter and 6–8 mm in depth. Holes are drilled in the base of the socket to create vascular channels and enhance graft incorporation.

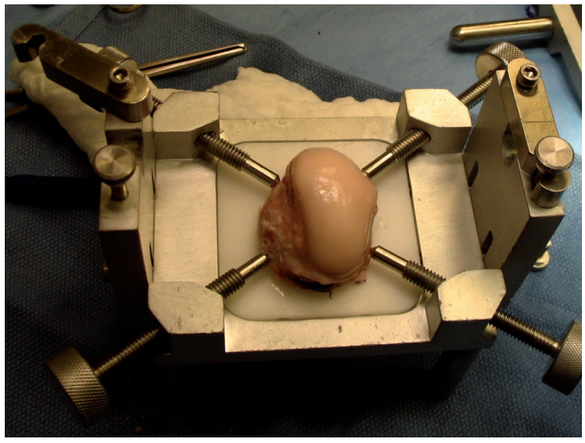

Fig. 3 – A hemicondyle is secured within the allograft workstation prior to cutting the osteochondral plug. Initially, the hemicondyle was trimmed with an osteotome to create a flat base.

damaging the articular surface (Fig. 4). The osteochondral plug is placed in the holding forceps and trimmed to match the depth of the recipient socket in the four quadrants (Fig. 5A). The allograft plug is then power-washed with pulsatile lavage to remove any residual marrow elements and decrease the risk of disease transmission and immune response (Fig. 5B). If the lesion is not amendable to a circular graft, a shell graft can be fashioned free hand in a trapezoidal configuration that matches a hand-prepared defect bed using a motorized burr and oscillating saw with cold irrigation. Freehand sizing of the graft is more time-consuming and often requires fixation because the fit is less precise.

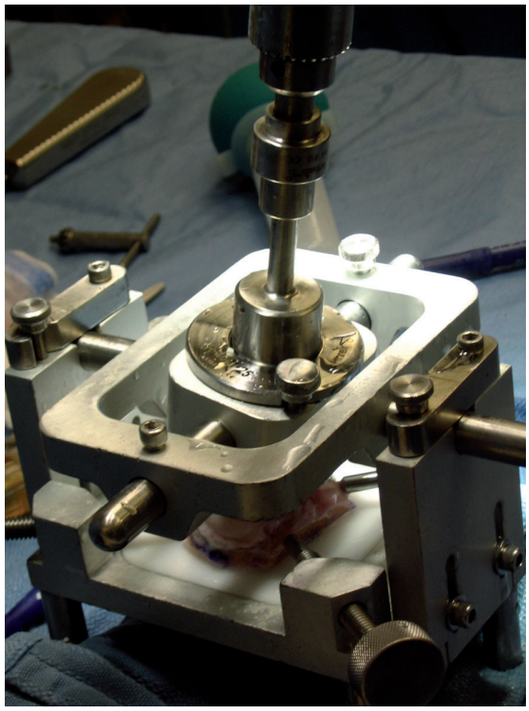

Fig. 4 – The drill guide is attached to the allograft workstation – aligned to match graft curvature to the recipient site. A full thickness osteochondral plug is drilled through the guide with lavage.

Before graft placement, a calibrated dilator is used to dilate the recipient socket an additional 0.5 mm. The graft is press-fit into the socket with careful attention to graft orientation (Fig. 6A). Once the graft has preliminary fit in the socket, it is gently impacted with the use of an oversized tamp to seat it completely. If the graft is particularly uncontained and or a minimum of 20 mm in diameter, fixation can be achieved with headless bioabsorbable compression screws (Arthrex Inc.) or metal screws (Fig. 6B). These steps should result in a graft that is securely positioned, well seated, and matches the contour of the neighboring host articular cartilage.

The incision is closed in standard fashion with no. 1 Vicryl or no. 2 Ethibond for the arthrotomy and no. 2 Vicryl for the subcutaneous tissue and a standard skin closure. Drain placement is usually unnecessary after osteochondral allografting. The knee is bandaged and braced in full extension. Cryotherapy is initiated immediately after surgery.

Postoperative rehabilitation

The outcome of osteochondral allograft transplantation relies on time-dependent maturation and remodeling of the subchondral bone. In order to

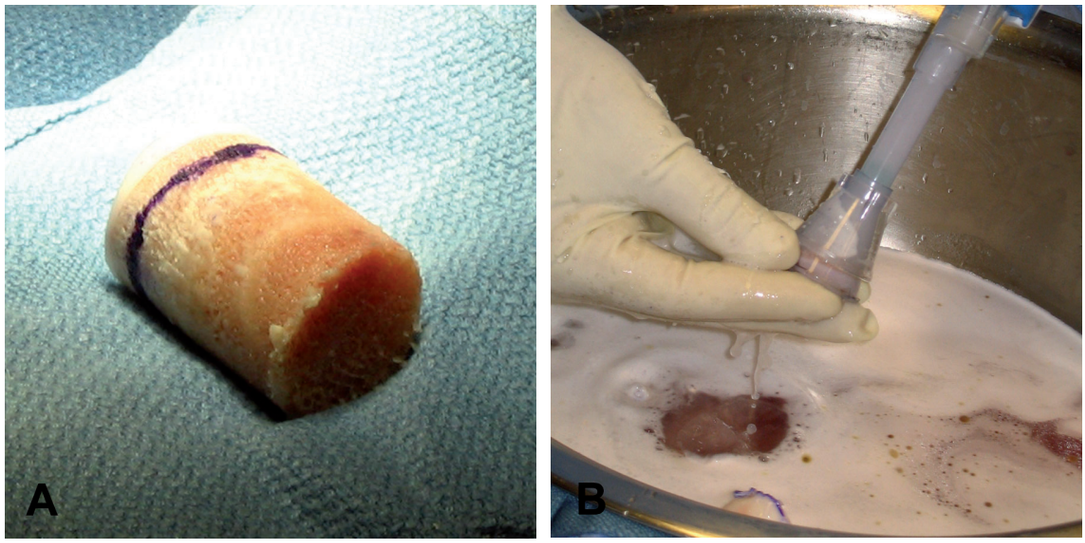

Fig. 5 – (A) A full-thickness osteochondral plug is marked to match the depth in all four quadrants of the recipient socket. (B) The plug is rinsed thoroughly with pulsatile lavage to remove immunogenic marrow elements remaining in the graft.

achieve this goal, patients must be compliant with the postoperative rehabilitation protocol. Postoperatively, weight bearing is limited for a minimum of 8 weeks. Continuous passive motion is initiated early to regain range of motion and facilitate healing. It provides mechanical stimulation for chondrocyte growth and orientation, while preventing premature overload of the graft. Subchondral collapse of the graft may occur if it is prematurely loaded. For that reason, high-impact sports are often limited following osteoarticular allografting because of concerns for graft collapse and graft deterioration (7).

Surgical outcome

Osteochondral allografting to the knee has been reported in the literature for more than two decades. Outcomes of femoral condyle allografting represent a significant segment of published studies with a consensus of 70–80% success. Patients with OCD in the condyle had significant improvement in their D'Aubigne & Postel and Subjective Knee Function scores at a mean of 7.7 years after implantation (8). McCulloch *et al.*'s patient population had an 84% satisfaction rate with significant improvements in Lysholm, IKDC, and KOOS scores (9). Graft survivorship in the femoral condyles is estimated to be 95% at 5 years and 85% at 10 years (10). Etiology (posttraumatic vs. osteochondritis dessicans) and condyle location do not appear to affect the outcome.

Allografting to the tibial plateau, trochlea, and patella occurs less frequently; consequently, limited reports are available on the success and durability of these grafts. In 65 unilateral tibial grafts, Kaplan Meier survival was 80% at 10 years with 21 knees converting to total arthroplasty at an average of 9.7 years (11). At a mean of 7.5-year follow-up, Ghazavi *et al.* had 86% good-to-excellent results and a 10-year survival rate of 71% (2). Bipolar resurfacing of the tibiofemoral joint as a salvage procedure to delay arthroplasty has had limited clinical success. In one cohort of six reciprocal transplants, articular allograft failure occurred in all three lateral and one of three medial transplants (12).

Success of patellar and combined patellar and trochlear allografting has been variable in small patient cohorts. In 8 isolated patellar and 12 combined grafts, 12 patients had good-to-excellent ratings compared with 5 grafts failures (2 patellar, 3 combined). Graft survival in this cohort was calculated to be 67% at 10 years (13). Elsewhere, bipolar patellofemoral resurfacing has had good or excellent results in 58–75% of patients. Isolated low volume reports of patellar allografting are contradictory with both high rates of success and failure (12,14). In actuality, the frequency of success is likely to be intermediate – undoubtedly lower than condylar allografts.

Treatment options for a failed osteochondral allograft are limited to reallografting or conversion to a unicompartmental or total arthroplasty. Factors that increase the frequency of graft failure include reciprocal defects, malalignment, worker's compensation patients, higher body mass index, and older age (2). Concurrent meniscal allograft transplantation or realignment are widely recognized and employed for risk modification. For patellar and tibial allografts, the "salvage" nature

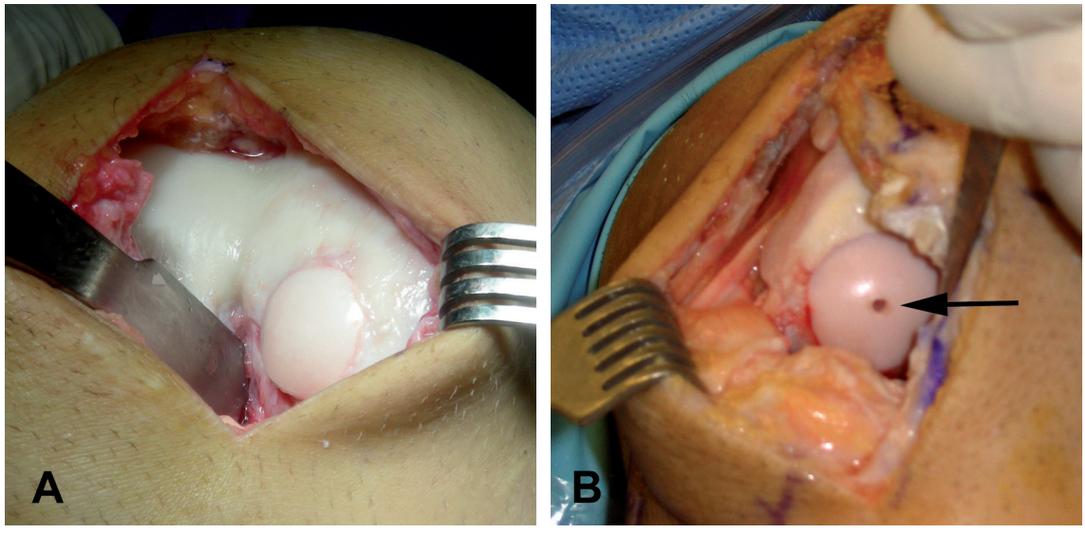

Fig. 6 – (A) A press-fit 25 mm osteochondral plug to the medial femoral condyle. (B) Fixation of a 25 mm osteochondral plug to the lateral femoral condyle is achieved with a bioabsorbable screw (arrow) through the graft.

Table 1 – Published reports on osteochondral allografts

Author	Follow-up time (year)	Number	Good/excellent results (scale)	Survival (10 years)	Graft failure
Emmerson *et al.* (8)	7.7 (2–22)	66 FC	47/65 (72%) D'Aubigne & Postel	76%	10
Gross *et al.* (10)	10 (45–22)	60 FC	40/60 (67%) HSS score	85%	12
Shasha *et al.* (11)	12 (5–24)	65 TIB	HSS score	80%	21
Ghazavi *et al.* (2)	7.5 (2–20)	63 TIB	54/63 (86%) HSS score	71%	7
		8 FC+TIB	4/8 (50%) HSS score		4
Chu *et al.* (12)	6.3 (1–12)	6 FC+TIB	2/6 (33%) D'Aubigne & Postel	n/a	4
		5 PT	5/5 (100%) D'Aubinge & Postel		0
		4 TR+PT	3/4 (75%) D'Aubigne & Postel		1
Torga Spak and Teitge (14)	10 (3–18)	2 PT	0/2 (0%) KSS & Lysholm	71%	2
		12 TR+PT	7/12 (58%) KSS & Lysholm		4
Jamali *et al.* (13)	7.8 (2–18)	8 PT	12/20 (60%) D'Aubigne & Postel	67%	5
		12 TR+PT			

of the procedure should be acknowledged by both surgeon and patient.

The role of osteochondral allografting in articular cartilage restoration – especially to the femoral condyle – is widely validated in the literature. With adequate technical proficiency on the part of the surgeon and compliance to the rehabilitation protocols, nearly 80% of patients will achieve clinical success – improvements in pain and function. Overall, the survivorship of these grafts is nearly 90% at 5 years and 80% at 10 years.

Pearls

- *Patient selection*: young, high demand individual with a localized, symptomatic, unipolar lesion (grade III–IV) of the femoral condyle
- *Evaluate and treat comorbidities*: evaluate for the presence of malalignment, meniscal deficiency, or ligamentous instability requiring correction
- *Imaging*: long axis films to assess alignment and sizing films for donor matching
- *Prepare recipient site*: create a perpendicular, shallow (6–8 mm) cylindrical socket – removing all fibrous tissue and sclerotic bone to form a viable allograft bed
- *Construct graft*: trim to the appropriate depth in all four quadrants of the socket and rinse with pulsatile lavage to decrease immunogenicity
- *Implant*: press-fit to minimize damage to articular surface; otherwise, utilize an oversized tamp to gently impact the allograft
- *Rehabilitate*: obtain range of motion early via continuous passive motion and limit weight bearing for 6–8 weeks to protect the articular cartilage surface

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