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Subchondral Bone Treatment

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Current Procedural Terminology Code	
27599	Unlisted procedure, femur or knee

Focal chondral defects and osteoarthritis are common causes of knee pain. Isolated articular cartilage lesions may progress, in size and symptoms, to degenerative arthritis. The biochemical and biomechanical relationships between articular cartilage and underlying subchondral bone play a significant role in the initiation and progression of osteoarthritis. The subchondral bone largely contributes to the presence of pain in chondral pathology of the knee.[1] Therefore, subchondral pathology, visible as sclerosis and/or cysts (plain radiographs) and hyperintensity (on magnetic resonance imaging [MRI]), has been targeted as a viable entity to treat in a therapeutic strategy to relieve pain.[2] Inhibition of subchondral lesions has been shown to alleviate joint pain.[1] Several arthroscopic and open surgical techniques have been used to address subchondral disease, including osteochondral autograft and allograft,[3] marrow-stimulation techniques,[4] autologous chondrocyte implantation via sandwich technique,[5] unloading osteotomy,[6] arthroplasty,[7] and Subchondroplasty (Zimmer Knee Creations).[8] Subchondroplasty is a minimally invasive technique in which a flowable osteoconductive bone void filler (calcium phosphate) is injected into the subchondral bone that corresponds to the area of bone marrow edema on MRI. The injected bone substitute stabilizes the subchondral bone mechanical insufficiency, which may provide pain relief through bone reconstitution with time. This chapter reviews the patient presentation, management algorithm, and surgical technique for Subchondroplasty.

Indications and Contraindications

The presence of a chondral or osteochondral lesion in the knee does not necessarily indicate pain.[9] Therefore, surgical treatment of chondral or osteochondral lesions in the knee should be based on symptoms that have persisted following nonoperative management (rest, activity modification, oral and injectable anti-inflammatory medications, bracing, physical therapy). In conjunction with arthroscopy, Subchondroplasty is indicated for treatment both of medial and lateral femoral condyle and tibial plateau lesions (Table 12-1). Patients who have symptomatic osteochondritis dissecans (OCD) lesions with stable intact overlying articular cartilage may be indicated for Subchondroplasty. Patients with osteoarthritis who want a nonarthroplasty surgical option may be indicated for Subchondroplasty.

Cole BJ, Harris JD, eds.
Biologic Knee Reconstruction: A Surgeon's Guide (pp 83-89).

Preoperative Patient Education Material

- How big are my incisions?
  - You will have 3 or 4 small incisions. Two incisions are for the arthroscopic "scope" portion of surgery. One or 2 incisions are used for drilling the bone and placing the Subchondroplasty calcium phosphate bone substitute.
- What is injected into my bone? Is it cadaver bone?
  - No, it is not cadaver bone. It is synthetic, meaning it is produced in a laboratory. The substance is osteoconductive, meaning it serves as a scaffold to allow new bone to grow into it.
- Will I need crutches after surgery?
  - Yes. For 2 weeks following surgery, you will use 2 crutches, while placing only approximately 20 pounds of weight on your operative leg. This is only slight pressure on your tip toes as you walk. After 2 weeks, you will progress to full weight bearing as tolerated as soon as possible.
- Will I need a brace after surgery?
  - No. Immediately after surgery, we encourage you to bend your knee as much as pain permits.
- Do I need a motion machine after surgery?
  - No. Unless you also had a cartilage repair procedure (such as microfracture), you will not need a continuous passive motion (CPM) machine. You may bend your knee on your own using your own muscles and passively with the help of your physical therapist.
- When can I get back to sports?
  - Depending on your specific sport, once you have full range of motion, with full muscle strength, reduced or no pain, no swelling, and no feelings of knee instability.

Table 12-1. Potential Indications for Femoral Condyle and/or Tibial Plateau Subchondroplasty

INDICATIONS	CONTRAINDICATIONS
• Chondral defects	• Acute tibial plateau fractures
• Osteochondral defects	• Acute distal femur fractures
• Osteochondritis dissecans	• Undiagnosed bone lesions
• Osteoarthritis	• Infection
• Insufficiency fractures	• Malignancy
• Stress fractures	
• Subchondral defects	
• Avascular necrosis	
• Spontaneous osteonecrosis of the knee	

Subchondroplasty is not appropriate for the treatment of undiagnosed bone marrow lesions that may represent potential primary or metastatic neoplasm, infection, or acute traumatic fractures around the knee (see Table 12-1).

Decision making in the surgical treatment of OCD lesions and chondral pathology (from isolated chondral defect to diffuse osteoarthritis) is multifactorial. Patient-specific (eg, age, gender, body mass index, smoking status,

Figure 12-1. (A) Sagittal and (B) coronal T2-weighted MRI of 10-year-old female with open physes with subchondral bone marrow edema.

Preference Card and Instrumentation

- Portable fluoroscopic unit (large or miniature C-arm)
- Radiolucent operating table (if large C-arm used)
- 30-degree arthroscope, tower, fluid, pump
- Mechanical shaver, arthroscopic forceps, basket, grasper
- Microfracture awls
- Battery power, drill with chuck attachment
- 2.4-mm, 3.2-mm guide pin
- 11-mm × 120-mm fenestrated delivery cannula
- 1-mm Luer lock syringes
- Subchondroplasty calcium phosphate bone substitute

activity level, symptom duration, number of prior surgeries, expectations), limb-specific (eg, alignment, muscle strength, range of motion), knee-specific (eg, meniscus status, ligamentous stability), and defect-specific (eg, size, shape, location, depth, prior surgical interventions) characteristics play a significant role in treatment choice. Thorough preoperative planning includes weight-bearing plain radiographs, long-leg alignment films, and high-quality MRI with fluid-sensitive series in all planes. Pain emanating from the subchondral bone that corresponds to the location of bone marrow edema (Figure 12-1) identified on MRI (hyperintensity visualized on fluid-sensitive series such as T2-weighted, fat-suppressed or short-tau inversion recovery [STIR]) is the target for the Subchondroplasty injection.

Surgical Technique

Patients are positioned on a radiolucent operating room table in the supine position. A tourniquet is applied, but is not necessarily inflated. After sterile preparation and draping of the lower extremity, diagnostic arthroscopy is performed. This is recommended to treat any concomitant intra-articular knee pathology, including meniscus, articular cartilage, loose bodies, synovium, and capsule. If articular cartilage lesion(s) is(are) identified that may warrant intervention, standard articular cartilage defect management algorithms are used.[10] Once the arthroscopic portion of the case is completed, the fluoroscopy unit is draped for use.

Pearls and Pitfalls

PEARLS	PITFALLS
• Thorough preoperative planning to exactly localize the intended treatment area based on MRI edema • Standard cartilage palliation, repair, and restoration techniques as indicated for arthroscopic portion of case • Reduced weight bearing for 2 weeks following surgery, while encouraging full motion • Use of 1-mL syringes. Larger sizes do not permit easy flow of calcium phosphate. Up to 3 or 4 syringes are commonly used per defect	• Improper positioning of patient on table if not using large C-arm. Ensure lateralization so that anteroposterior and lateral mini-C-arm images may be obtained • Incomplete filling of the defect • Removing delivery cannula too soon (less than 5 minutes after final syringe) will cause leakage of calcium phosphate

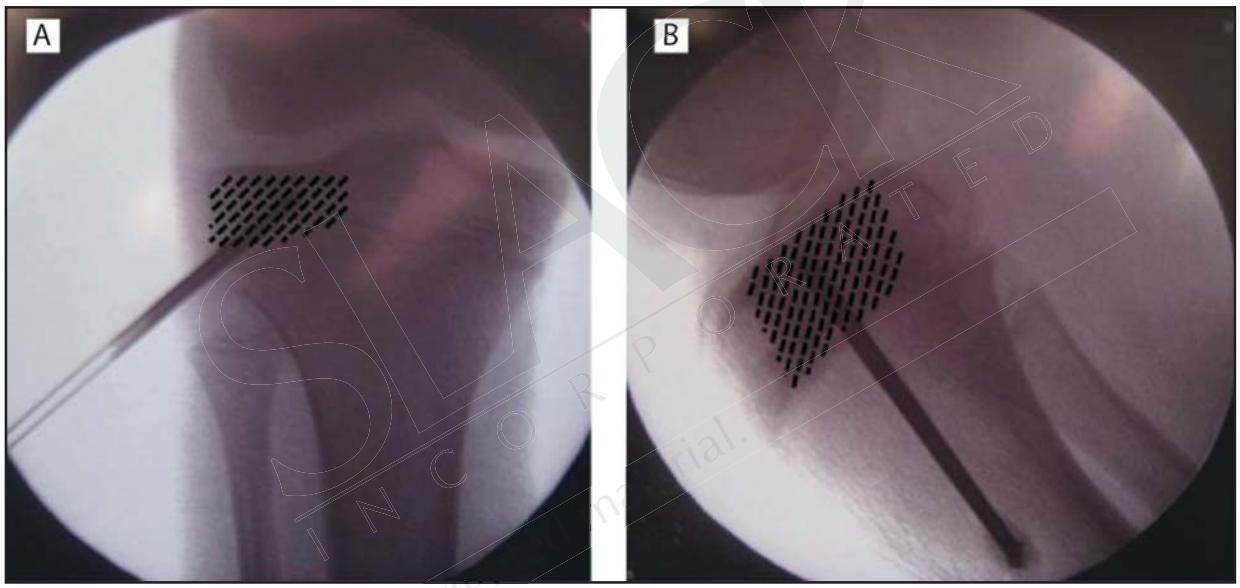

Figure 12-2. (A) Anteroposterior fluoroscopic image demonstrating the delivery cannula in the intended location, based on preoperative MRI location of maximal edema. The dashed lines illustrate the MRI edema. (B) Lateral fluoroscopic image demonstrating the delivery cannula in the intended location, based on preoperative MRI location of maximal edema. The dashed lines illustrate the MRI edema.

The technique is as described in the manufacturer's instructions (Zimmer Knee Creations). Fluoroscopy (either large or miniature C-arm) is used to identify the treatment area via fluoroscopic navigation guide and delivery cannula. A semicircular guide (optional) is used around the tibia to target any specific location with a range of access trajectories (Figure 12-2). Two 2.4-mm stabilization pins attach the guide anteriorly to the tibia. Using fluoroscopic guidance, one 3.2-mm bladed pin is inserted through the appropriate trajectory hole to the appropriate depth based on preoperatively planned imaging. After the pin has reached the intended location, the guide is removed with the pin retained. The Subchondroplasty fenestrated delivery cannula (11 mm × 120 mm) is then placed over the guide pin, advanced into the bone to the target location (see Figure 12-1), and the guide pin removed. A Luer-lock 1-mL syringe filled with Subchondroplasty calcium phosphate is then attached to the delivery cannula. The bone substitute is then injected into the defect (Figure 12-3). Additional 1-mL syringes (Figure 12-4) are used as needed to fill the defect completely. Residual calcium phosphate is pushed down the syringe using the delivery cannula trocar. The calcium phosphate is allowed to set for a minimum of 5 minutes prior to removal of the cannula. Final fluoroscopic images demonstrate complete filling of the defect (Figure 12-5). During the process of injection, an arthroscope may be placed back into the affected compartment to ensure that calcium phosphate remains in the

Figure 12-3. Intraoperative photograph demonstrating delivery cannula with attached 1-mL syringe and calcium phosphate injection.

Figure 12-4. One-mL syringes filled with calcium phosphate bone substitute.

Figure 12-5. Final anteroposterior fluoroscopic image demonstrating complete filling of the defect with radio-opaque calcium phosphate in lateral proximal tibial epiphysis in skeletally immature individual.

bone without intra-articular extravasation. However, if a marrow-stimulation technique was performed, then intra-articular extravasation of calcium phosphate confirms the proper location of the extra-articular Subchondroplasty injection. The bone substitute may easily be removed using a mechanical shaver or suction.

Postoperative Rehabilitation

Postoperative rehabilitation ensues immediately following surgery. Standard protocols regarding articular cartilage techniques are used, especially regarding early motion. Strictly with regard to Subchondroplasty, no restriction is placed on range of motion. However, weight bearing is initially restricted to partial (~20 pounds) for the first 2 postoperative weeks.[8] After 2 weeks, weaning from crutches is initiated with progression to full weight bearing as tolerated.

Clinical Outcomes

The treatment of subchondral bone marrow lesions in the setting of articular cartilage pathology with Subchondroplasty has limited yet promising short-term clinical outcomes. Other surgical treatments that replace the bone defect (osteochondral autograft, allograft) are well described as successful treatment options. Clinical outcome studies on arthroscopy with subchondral injection of calcium phosphate are mainly limited to the treatment of depressed tibial plateau fractures in conjunction with balloon osteoplasty ("tibioplasty"). Abrams et al described a skeletally immature female with a symptomatic OCD lesion of the lateral tibial plateau that had failed conservative measures and underwent knee arthroscopy, microfracture, and Subchondroplasty.[8] The injection of calcium phosphate bone substitute was fluoroscopically guided and targeted to the area of maximal edema on the preoperative MRI (at the intersection of hyperintensity on sagittal, coronal, and axial series). Postoperatively, the patient had significant improvement in pain at the lateral tibial plateau. The technique has also been used in the setting of osteoarthritis and spontaneous osteonecrosis of the knee. Currently, clinical outcomes are yet to be reported on these subject populations.

Bone marrow edema has been strongly linked to presence and progression of pain in the setting of knee osteoarthritis.[11,12] Further, it is associated with progression of cartilage degeneration, acceleration of joint degeneration, and is a predictor of knee arthroplasty.[11,12] In patients with focal chondral defects that have failed prior marrow-stimulation techniques, the rate of failure of autologous chondrocyte implantation is significantly increased (up to 3 times greater).[13] This is likely due to the subchondral bone remodeling from the marrow-stimulation procedure. This finding of sclerosis and intralesional osteophyte formation is not uncommon following marrow-stimulation surgeries.[14-16] Angiogenesis and nerve neogenesis, along with both noncalcified and calcified tissues, have illustrated the mechanism of pain in patients with osteoarthritis, especially at bone marrow lesions.[17,18] However, simply

Outcomes of Subchondral Bone Surgery				
AUTHORS	**JOURNAL**	**NUMBER OF PARTICIPANTS**	**INTERVENTION**	**OUTCOMES**
Abrams et al[8] (2013)	*Arthroscopy*	1	Subchondroplasty, microfracture	• Case report of 10-year-old female with recalcitrant right knee pain related to lateral tibial plateau OCD • Subchondroplasty calcium phosphate injected into right lateral tibial epiphysis at point of maximal edema on T2 series • Short-term outcome of improved pain
Mauffrey et al[19] (2013)	*Patient Saf Surg*	20	Balloon osteoplasty	• Retrospective case series of 20 individuals (mean age 43 years) with depressed tibial plateau fractures-calcium phosphate cement • 40% of cases had balloon burst during inflation, with dye extravasation; 25% had extravasation of calcium phosphate into knee joint
Sharkey et al[11] (2012)	*Am J Orthop*	1	Subchondroplasty	• Case report of overweight 51-year-old female with knee osteoarthritis and bone marrow edema in medial tibial plateau • 31-month follow-up, active lifestyle, 1/10 pain, no further treatment needed • MRI showed resolution of edema
Pizanis et al[20] (2012)	*J Orthop Trauma*	5	Balloon tibioplasty	• Retrospective case series of 5 patients (mean age 62 years) with depressed tibial plateau fractures-calcium phosphate cement • At 12- to 36-month follow-up, osteointegration observed • No complications, no extravasation

the presence of edema on MRI is not sufficiently satisfactory to explain the presence of pain in some patients.[21] Filardo et al performed hyaluronic acid-based matrix associated chondrocyte transplantation in 116 individuals with focal chondral defects and OCD lesions.[21] Postoperative MRI 6 to 108 months following surgery revealed that edema was common for 2 years after surgery, then markedly reduced or absent between 2 and 3 years. Following 3 years, the edema returns and remains indefinitely. OCD lesions had significantly greater amounts of edema at all time points following surgery. Regardless of diagnosis, no correlation was observed between edema and clinical outcome. Nonetheless, edema on MRI corresponds to fibrosis, necrosis, edema, bleeding of fatty marrow, abnormal bony trabeculae, angiogenesis, and growth of nociceptive nerve fibers,[22] thus making it a viable target for surgical treatment with subchondral injection of bone substitutes such as calcium phosphate.[8]

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