Surgical Treatment of Osteoarthritis Pain Related to Subchondral Bone Defects or Bone Marrow Lesions: Subchondroplasty

Steven B. Cohen, MD† and Peter F. Sharkey, MD*†*

Abstract: Bone marrow lesions (BMLs) are a recently identifiable cause of knee pain in patients with degenerative joint disease. BMLs are understood to be a stress reaction, bone defect, or fracture of the knee. A potential opportunity exists to healing and relief of patient symptoms through treatment of BMLs. In this report, we describe a method of treatment for these bone defects known as BMLs. Notwithstanding our promising results with this technique, further study is required to determine the most appropriate candidates who would benefit from this treatment.

Key Words: bone marrow lesions, knee osteoarthritis, Subchondroplasty

(*Tech Knee Surg* 2012;11: 170–175)

HISTORICAL PERSPECTIVE

Since the mid-90s,[1] a steady increase in the use of magnetic resonance imaging (MRI) for patients with knee pain has led to interest in the role of bone marrow lesions (BMLs) in knee osteoarthritis (OA) and progressive joint disease. Given their frequent presence, BMLs were originally described as a marker of worsening OA.[2] However, a significant body of literature has shown that BMLs represent structural changes in the subchondral bone that are often a precursor to and speed the deterioration of the joint.[3,4] The presence of BMLs has been shown to correlate strongly with the presence of pain in knee OA.[5] Patients with BMLs have been shown to have more rapid cartilage destruction,[3] subchondral bone attrition,[4] and to be more likely to move on to a total knee arthroplasty (TKA).[6]

As BMLs represent a stress reaction in the joint to focal loading,[7] a number of conservative treatment options may offer patients relief or promote resolution of the pathologic process. Nonoperative treatment options range from rest and physical therapy, including low-impact exercises, to the use of oral nonsteroidal anti-inflammatory medicines.[8] It has been suggested that injection of corticosteroids or viscosupplementation may leech into the subchondral bone and reduce inflammation or promote healing, thus reducing pain.[9] Additional treatments include weight loss, or unloader bracing to reduce the overall contact forces in the affected compartment. These treatments have met with varied success rates, particularly for BMLs that have become chronic in nature.[8]

Surgical treatment to reduce joint contact stress may include osteotomy of the tibia or femur for younger patients with lower extremity malalignment (varus or valgus). In addition, TKA or unicompartmental knee arthroplasty (UKA) may be performed to excise the arthritic bone and realign the joint to evenly distribute joint stress. Results of these techniques vary as studies have shown recurrent pain from osteotomy 5 to 7 years after surgery, and an average 20% dissatisfaction rate from total knee replacement.[10] In addition, the postoperative rehabilitation, surgical morbidity, and complication rates have rendered both osteotomy and TKA less popular with middle-aged or active patients.[11,12] Furthermore, younger patients who undergo TKA or UKA are subject to requiring revision surgery as bearing surfaces wear with increasing activity.[13]

A minimally invasive surgical intervention that delivers reliable resolution of the affected subchondral bone while preserving the native joint remains a possible solution and delay the need for arthroplasty. Histologic analysis of BMLs from resected tibial plateaus during TKA has shown the pathologic region to contain very little true edema. Rather, the area of high-signal intensity on fat-suppressed MRI represents an area fibrosis, necrosis, and microcracks or microfractures.[14–16] In sum, the subchondral bone is experiencing a failed remodeling because of the continued stresses, or a reduced capacity to heal. This report focuses on a surgical technique known as Subchondroplasty (SCP), which aims to focally treat the diseased area of subchondral bone seen on T2-weighted MRI scans.[17]

INDICATIONS AND CONTRAINDICATIONS

MRI is required both to rule out other driving symptoms of pain and properly identify the presence of a BML. The primary indication for the SCP procedure is presence of BML on fat-suppressed T2-weighted MRI associated with pain localized to the affected compartment on load bearing. Palpation of the bone above and below the joint line may also be used to correlate the location of the lesion on MRI with the patient's symptoms.

It is well recognized that it can be difficult to diagnose subchondral bone defects or BML in an osteoarthritic patient because they commonly occur in combination with other degenerative changes. Multiple factors must be considered when evaluating a patient with a suspected BML and a thorough knee examination is required. In patients presenting either acute or with chronic pain, the history of the mechanism of injury and clinical examination are the first steps in patient evaluation. Patients with recent onset of pain (< 3 mo) or acute sports-related injury or trauma should be recommended a course of conservative care. These acute bone bruises typically resolve with rest particularly in the setting of normal healthy bone and minimal malalignment.[18]

Knee examination should establish range of motion of the affected knee and ligamentous stability. Patients may have additional locking or catching of the knee from concomitant meniscal, chondral, or loose body pathology which is not considered a contraindication. Patients with deficient anterior cruciate ligament/posterior cruciate ligament may be considered candidates for SCP as long as they have no clinical complaints of instability.

From the *Rothman Institute Orthopaedics; and †Department of Orthopaedic Surgery, Thomas Jefferson University, Philadelphia, Pennsylvania.
Drs Cohen and Sharkey wish to note that they are consultants for and receive royalties from Knee Creations, LLC.
Address correspondence and reprint requests to Steven B. Cohen, MD, Rothman Institute Orthopaedics, 925 Chestnut Street, Philadelphia, PA 19107. E-mail: steven.cohen@rothmaninstitute.com.

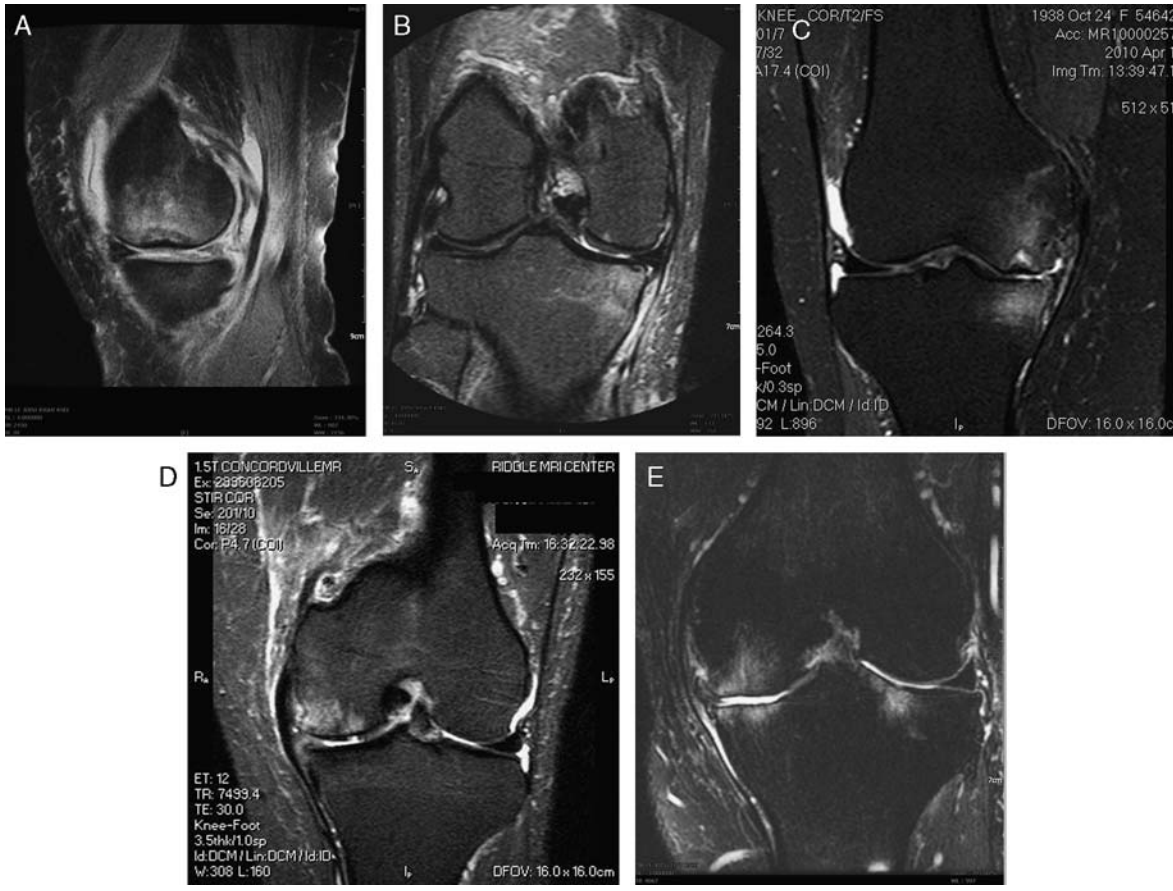

FIGURE 1. Treatable bone marrow lesion patterns.

Standard weight-bearing anteroposterior (at 0 and 30 degrees of flexion), sunrise, and lateral knee radiographs are used to rule out fractures, dislocations, or large osteocondritis dissecans lesions. These conditions would be considered contraindications. Standing radiographs should be used to determine joint alignment. Patients with severe malalignment of the joint, defined as >8 degrees varus/valgus should not be treated with the SCP procedure without a simultaneous correction of joint alignment.

Bone cysts, represented by well-circumscribed areas of bright intensity that have not been shown to be painful and are not candidates for treatment.[19] Subspinous or central tibial BMLs, often located at the insertion of the anterior cruciate ligament/posterior cruciate ligament are not considered candidate for treatment.[20] Large BMLs of the tibia or femur, sometimes inaccurately referred to as spontaneous osteonecrosis of the knee or avascular necrosis may be treated with the SCP procedure in a precollapse state. Patients showing severe attrition or collapse of the subchondral plate should not be treated with SCP as the procedure will not restore tibial plate height (Fig. 1).

Surgeon should rule out general synovitis of the joint, Hoffa synovitis, or ganglion or baker's cyst, or inflammatory arthropathy as the primary cause of knee pain. However, in combination with painful BML, these conditions are not considered contraindications and may be treated simultaneously (Fig. 2).

Patients may present with varying degrees of cartilage thinning or loss. Cartilage damage often occurs in concert with BMLs, and is not considered a contraindication for treatment. However, full-thickness cartilage loss in all 3 compartments of the knee should be considered a contraindication as these patients are likely better served by TKA.

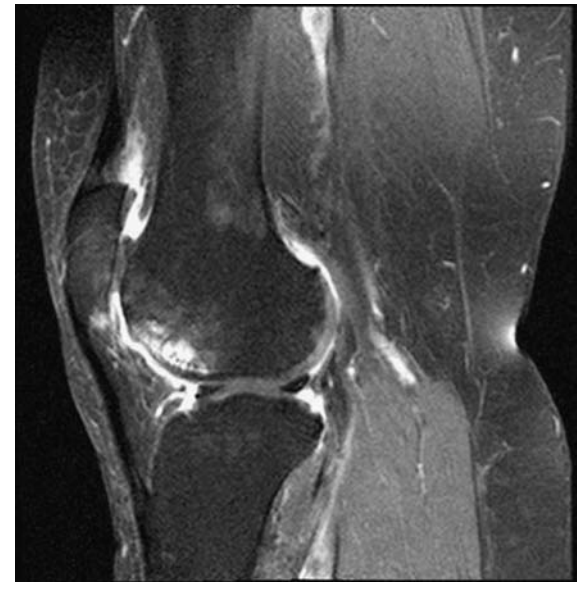

FIGURE 2. Bone marrow lesion pattern in a patient with multiple concomitant issues.

RADIOGRAPHIC ASSESSMENT AND PREOPERATIVE PLANNING

MRI of the affected knee no more than 3 months before surgery should be used for preoperative planning. BML can be identified on fat-suppressed MR images including T2 Fat Sat, Proton Density (PD) Fat Sat, or short TI inversion recovery. All the 3 MRI planes (axial, coronal, and or sagittal) should be used to triangulate the location of the BML in the joint (Fig. 3). Measurement tools on digital MR software may additionally be helpful in determining the distance of the lesion from the articular surface and or cortical wall as well as determining the volume of the lesion.

A preoperative determination should be made as to the extent and volume of the BML. The magnetic resonance imaging osteoarthritis knee scoring system suggests determining the extent of the edema relative to the compartment as well as scoring the volume in 3 dimensions. The preferred trajectory to access the lesion (parallel to the joint line vs. angled toward the articular surface) should be determined relative to ligamentous structures.

MR images have traditionally been useful for determining the presence of meniscal pathology, synovitis, loose bodies, and chondral damage. All intra-articular pathology can be addressed at the time of arthroscopy in an effort to reduce many causes of patient discomfort.

TECHNIQUE

The operation is performed with the patient supine using a sterile thigh tourniquet on a radiolucent operating table, and a lateral post is used for arthroscopy. The patient is placed under general or spinal anesthesia. The nonoperative knee is padded and placed flat on the operating table (Fig. 4).

An examination under anesthesia is completed to determine range of motion and ligamentous stability. In all cases, a diagnostic arthroscopy is performed to assess all intra-articular structures. Standard arthroscopic evaluation of the knee is carried out and all 3 compartments (medial, lateral, and patellafemoral) are inspected for cartilage damage and graded based on Outerbridge and international cartilage repair society scales, and a debridement chondroplasty is performed for loose chondral flaps. The medial and lateral meniscus are probed and any tears are treated with debridement and contouring as necessary. In addition, any loose bodies or chondral debris encountered is also removed. The anterior and posterior cruciate ligaments are probed for stability.

Once the arthroscopy is completed, the operative leg is placed on a bump or a basin to elevate the operative leg to obtain a lateral fluoroscopic view (Fig. 5). A true lateral fluoroscopic view is obtained by aligning the femoral condyles and the medial and lateral aspects of tibial plateau. The medial

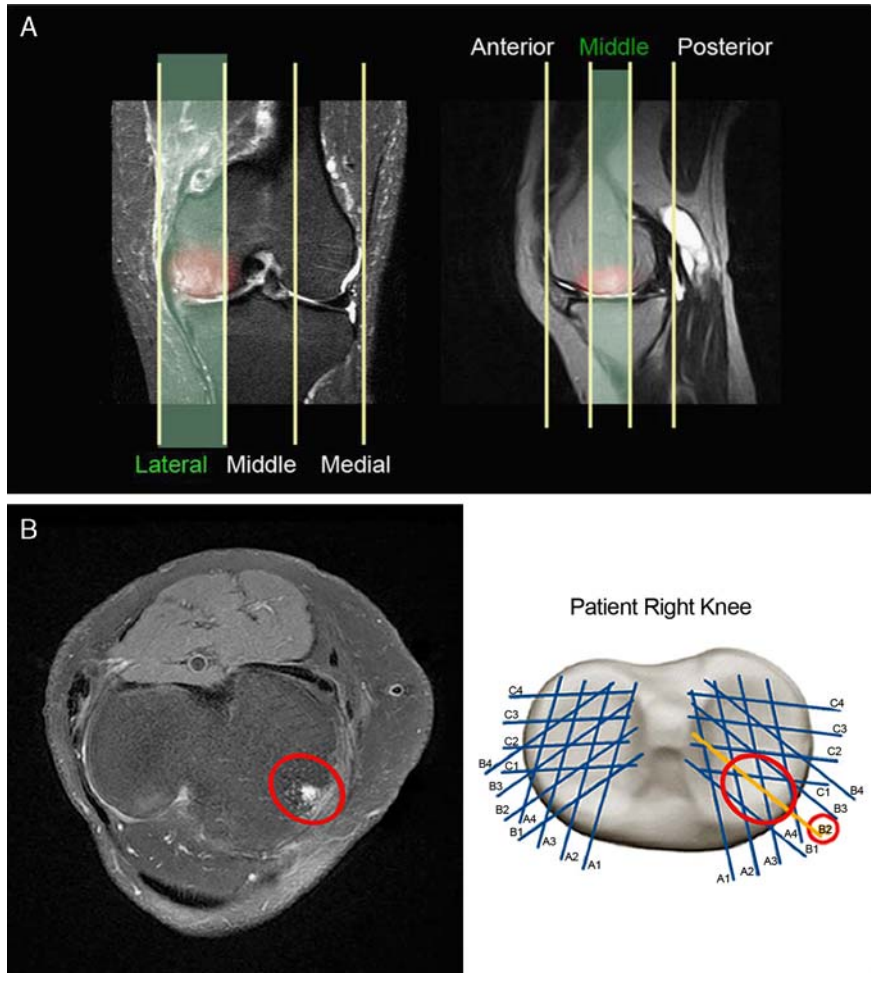

FIGURE 3. Example of tibial (B) and femoral (A) condyle mapping.

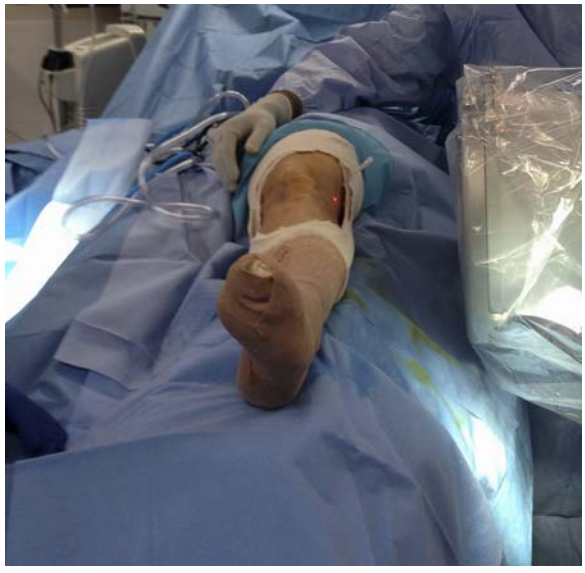

FIGURE 4. Patient positioning.

and lateral joint lines and patellar tendon are then marked on the skin.

To treat a tibial lesion, a navigation guide may be utilized by placing it on the anterior portion of the knee such that the access portals of the guide lay over the subchondral bone (5 to 10 mm below the articular surface). The guide should demarcate the tibial plateau and the posterior edge of the tibia. The tibial tubercle can be used as a stabilizer for a navigation frame. Once the guide is in place, the trajectory that was predetermined by the 3 views on MRI and mapping guide can be utilized to accurately place a fenestrated cannula into the BML. The cannula placement is confirmed on orthogonal fluoroscopic views.

Remove the trocar from the cannula and luer-lock a syringe with an injectable synthetic bone substitute to the cannula. Applying steady digital pressure, inject the bone substitute into the area of subchondral defects. The cannula can be rotated to direct the fenestrations toward the articular surface. Continue injecting bone substitute until a darkened blush is visible on the fluoroscope that mimics the pattern of the BML on MRI. Arthroscopic imaging is again used to confirm proper injection of the calcium phosphate (CaP) without extravasation into the joint space (Fig. 5).

To treat a femoral lesion, the navigation guide may again be used and placed over the femoral condyle so as to define the articular surface of the condyle and confirm the location of the injection. Similar to the tibial lesion, fluoroscopy is utilized to confirm the proper location of the pin placement and injection of the CaP. On the basis of the location of the lesion, the fenestrations of the cannula can be directed toward the articular surface if necessary (Fig. 6). As with the tibial lesion the surgeon needs to confirm that there is no extravasation of the injection into the joint by judiciously placing the material in the lesion and confirming the placement with arthroscopy. As the CaP is hydrophilic, any material can be flushed out of the joint with the arthroscope and shaver.

The properties of the commercially available CaP used in this technique are very important. The CaP must be injectable, flowable, and endothermic so as to not lead to osteonecrosis. The CaP bone substitute must be resorbed over time and replaced with healthy bone so as to induce healing of the damaged bone and restore the structural integrity of the cancellous bone. The material also needs to have similar structural properties of cancellous bone so as not to create a stress response. The resorbable, osteoconductive bone graft substitute used in this technique has been shown to promote healing. Finally, the resorbable bone substitute should be used so as to avoid compromising a future TKA if required.

COMPLICATIONS

There have been no significant medical complications encountered in the cases performed to date. Extravasation of the bone substitute into the joint of soft tissue is a potential complication that can be removed during the procedure. There have been no reactions noted from the bone substitute, however, bone substitute which has hardened in the soft tissue can be tender and noted by palpation. This has occurred in a few patients.

Patients have reported significant pain postoperatively for up to 72 hours after treatment, more than the typical knee arthroscopy. Pain management using narcotics or anti-inflammatory medicine is important. In addition, it is important not to over pressurize the bone substitute upon insertion.

The formation of a new BML in previously uninvolved compartment has been noted. The degenerative nature of the disease may continue to affect other compartments. Finally,

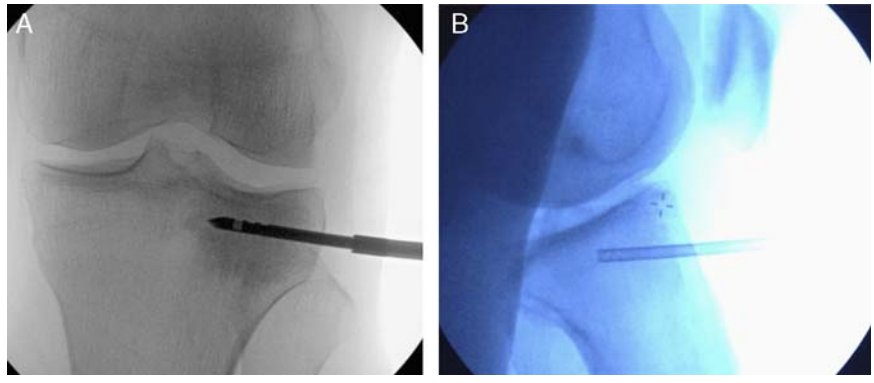

FIGURE 5. Implantation of bone substitute. A and B, Two unique patient examples.

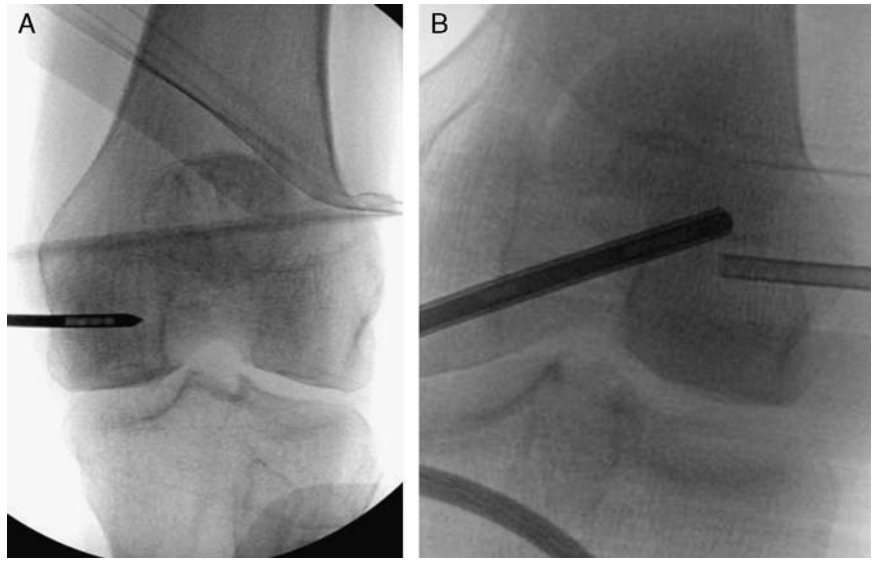

FIGURE 6. Implantation of BSM in the femur. A and B, Two unique patient examples. BSM indicates bone substitute material.

although not a complication, patients who have failed to obtain significant pain relief have been converted to TKA or UKA without making the index procedure more complicated.

POSTOPERATIVE MANAGEMENT

All patients were discharged the same day with optional use of narcotics for 24 to 72 hours after treatment to control the postoperative pain. Patients are evaluated approximately 7 to 10 days postoperatively to remove sutures and assess surgical healing. Patients are recommended to maintain weight bearing as tolerated with crutches for 1 to 2 weeks. Formal physical therapy is initiated within 2 weeks of the surgery and typically lasts for 4 to 8 weeks after surgery. Significant pain reduction and return to full activity may take up to 2 to 3 months from the time of the surgery.

POSSIBLE CONCERNS AND FUTURE OF THE TECHNIQUE

The SCP procedure is a truly minimally invasive intervention that appears to be a safe, effective, and joint-preserving treatment for pain associated with BMLs. A single-site cohort of patients has shown promising and long-lasting outcomes, however, more study is necessary to understand the long-term outcomes and the ideal patient definition.

Future advancement of the procedure may incorporate additional bioactive agents with the bone substitute to provide faster, more extensive bone remodeling in addition to the structural support.

REFERENCES

1. Blamire AM. The technology of MRI—the next 10 years? *Br J Radiol*. 2008;81:601–617.
2. Jimenez-Boj E, Nöbauer-Huhmann I, Hanslick-Schnabel B, et al. Bone erosions and bone marrow edema as defined by magnetic resonance imaging reflect true bone marrow inflammation in rheumatoid arthritis. *Arthritis Rheum*. 2007;56:1118–1124.
3. Wluka AE, Wang Y, Davies-Tuck M, et al. Bone marrow lesions predict progression of cartilage defects and loss of cartilage volume in healthy middle-aged adults without knee pain over 2 years. *Rheumatology*. 2008;47:1392–1396.
4. Roemer FW, Neogi T, Nevitt MC, et al. Subchondral bone marrow lesions are highly associated with, and predict subchondral bone attrition longitudinally: the MOST study. *Osteoarthritis Cartilage*. 2010;18:47–53.
5. Felson DT, Chaisson CE, Hill CL, et al. The association of bone marrow lesions with pain in knee osteoarthritis. *Ann Intern Med*. 2001;134:541–549.
6. Tanamas SK. Bone marrow lesions in people with knee osteoarthritis predict progression of disease and joint replacement: a longitudinal study. *Rheumatology*. 2010;49:2413–2419.
7. Segal NA. Baseline articular contact stress levels predicts incident symptomatic knee OA development in the MOST. *Cohort J Orthop Res*. 2009;27:1562–1568.
8. Richmond J. Treatment of osteoarthritis of the knee (nonarthroplasty). *J Am Acad Orthop Surg*. 2009;17:591–600.
9. Erikesen EF, Ringe JD. Bone marrow lesions: a universal bone response to injury? *Rheumatol Int*. 2012;32:575–584.
10. Beswick AD. What proportion of patients report long-term pain after total hip or knee replacement for osteoarthritis? A systematic review of prospective studies in unselected patients. *BMJ Open*. 2012;2:e000435.
11. Morrey BF. Complications and mortality associated with bilateral or unilateral total knee arthroplasty. *J Bone Joint Surg Am*. 1987;69:484–488.
12. Naudie D. The Install Award. Survivorship of the high tibial valgus osteotomy. A 10- to 22-year followup study. *Clin Orthop Relat Res*. 1999;367:18–27.
13. Harrysson OL. Higher cumulative revision rate of knee arthroplasties in younger patients with osteoarthritis. *Clin Orthop Relat Res*. 2004;421:162–168.
14. Taljanovic MS. Bone marrow edema pattern in advanced hip osteoarthritis: quantitative assessment with magnetic resonance imaging and correlation with clinical examination, radiographic findings, and histopathology. *Skeletal Radiol*. 2008;37:423–431.

15. Zanetti M, Bruder E, Romero J, et al. Bone marrow edema pattern in osteoarthritic knees: correlation between MR imaging and histologic findings. *Radiology*. 2000;215:835–840.
16. Hunter DJ. Bone marrow lesions from osteoarthritis knees are characterized by sclerotic bone that is less well mineralized. *Arthritis Res Ther*. 2009;11:R11.
17. Starr M. Bone marrow edema: pathophysiology, differential diagnosis, and imaging. *Acta Radiol*. 2008;49:771–786.
18. Boks SS. MRI follow-up of posttraumatic bone bruises of the knee in general practice. *AJR*. 2007;189:556–562.
19. Slavotinek JP, Wicks A, Spriggins AJ. Subperiosteal aneurysmal bone cyst with associated bone marrow oedema: an unusual appearance. *Australas Radiol*. 2003;47:475–478.
20. Javaid MK. Pre-radiographic MRI findings are associated with onset of knee symptoms: the most study. *Osteoarthritis Cartilage*. 2010;18:323–328.