**Technical Note**

**Hitting the Mark: Optimizing the Use of Calcium Phosphate Injections for the Treatment of Bone Marrow Lesions of the Proximal Tibia and Distal Femur**

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**Abstract:** Increased contact pressures of the osteoarthritic joint can lead to underlying osseous injury, with resultant marrow edema changes of the subchondral bone. These osteoarthritis-related bone marrow lesions can subsequently lead to persistent pain and further disability. Limited joint preservation treatment options exist to alleviate symptoms or potentially alter the natural history of the affected joint; however, recent success with injectable calcium phosphate has provided early pain relief and may provide a scaffold for endogenous repair mechanisms. In this Technical Note, a comprehensive surgical approach using injectable calcium phosphate to target bone marrow lesions of the proximal tibia and distal femur is presented. Critical technique considerations include the use of magnetic resonance and fluoroscopic imaging to target the area of the subchondral bone while refraining from overfilling and/or forced pressurization during delivery and the use of postinjection arthroscopy to prevent potential injurious sequelae.

The presence of subchondral bone marrow lesions (BMLs) of the knee can represent mechanical alterations of the underlying trabecular bone1-3 and has been associated with numerous pathologic conditions.4 The presence of BMLs can be found on magnetic resonance imaging (MRI) with fluid-sensitive sequences using fat suppression. In the setting of osteoarthritis-related BMLs, chronic overload leading to BMLs has been associated with increased pain and dysfunction5 and may lead to further joint degeneration when present.6 Although the course of subchondral BMLs can be variable, a majority of BMLs will remain the same or increase in size over time.7 This has led to a higher likelihood of patients undergoing total knee arthroplasty.8

An emerging option for treatment of osteoarthritis-related BML is the injection of an osteoconductive bone substitute material for osteoarthritis-related BML. This procedure, known as subchondroplasty (Zimmer Knee Creations, West Chester, PA), involves using calcium phosphate to provide mechanical support and initiating osseous remodeling at the site of injury. The goals of the calcium phosphate injection are to provide early pain relief and alter the course of a persistently symptomatic BML. Cohen et al.1 reported that patients with osteoarthritis-related BML treated with subchondroplasty using calcium phosphate had improved clinical outcomes at 2-year follow-up, with 70% forgoing joint arthroplasty. Bonadio et al.9 also reported significant improvements in pain and functional capacity in the short-term assessment. Although the benefit of calcium phosphate injection for osteoarthritis-related BML of the knee may be present, few reports have delineated technique considerations and combined procedures to optimize outcomes with this procedure.

In this report, a combined open and arthroscopic approach using a calcium phosphate injection to treat osteoarthritis-related BML of the proximal tibia and distal femur is detailed. Using this technique, the area of the subchondral bone is targeted; this area is susceptible
to increased focal contact pressures in osteoarthritis-related BMLs. It is important to inject the calcium phosphate into the subchondral bone immediately underlying the articular surface while preventing overfill or forced pressurization. Following delivery, knee arthroscopy is performed, allowing the opportunity to remove any calcium phosphate that may have extruded into the joint.

Surgical Technique

Patient Positioning and Room Setup

The patient is placed in the supine position on a radiolucent table to be used for intraoperative fluoroscopy during injection of the calcium phosphate. A radiolucent bump is used under the knee (Fig 1), which elevates the operative extremity and allows for unobstructed anteroposterior and lateral fluoroscopic views during the procedure. Standard arthroscopic instruments are set up for arthroscopy, which will be performed after completing the injection of calcium phosphate.

Fig 1. Patient positioning and room setup. The patient is placed in the supine position on a radiolucent table (left leg shown). A radiolucent bump is used under the knee, which elevates the operative extremity and allows for unobstructed anteroposterior and lateral fluoroscopic images. Standard arthroscopic instruments are set up for arthroscopy, which will be performed after completing the injection of calcium phosphate.

Localization and Exposure for Injection of Calcium Phosphate

A true AP view of the knee is first obtained while using a radiopaque surgical tool (e.g., clamp, injecting cannula) to localize the targeted area before incision (Fig 2). The radiopaque surgical tool should be positioned just proximal to the BML and approximately 1 cm from the articular surface. The AP image of the knee, which should be saved for reference, will be compared with the preoperative coronal MRI (Fig 3). Once the area has been localized on AP fluoroscopy images, a surgical marker is used to denote this area on the overlying skin, which will aid in establishing the position for eventual delivery of the injectable calcium phosphate. The fluoroscopic C-arm (OEC 9900 Elite, GE Healthcare; Little Chalfont, England) is positioned (Fig 4) to obtain a lateral radiograph of the knee (Fig 5) using the cannula to localize the target area as determined by preoperative sagittal MRI (Fig 6). Once again, the cannula is positioned just proximal to the BML and the skin is marked to establish the position in the AP dimension while using the lateral radiograph.

Using the skin markings to match positions on the AP and lateral imaging, a 2-cm incision is made through skin and underlying subcutaneous tissue (Fig 7). This incision allows the debridement or irrigation of any extravasated cement from the soft tissues. Dissection is then carried down to bone, and soft tissue is cleared to prevent interposition between the cannula and cortex. The cannula is then drilled into position under fluoroscopic guidance (Fig 8). The goal is to remain parallel to the joint surface and immediately below the articular surface. Either a side- or end-targeted cannula can be used for delivery; the selection can be based on size and location of the BML.

Fig 2. A true AP view of the knee is obtained while using a radiopaque surgical tool (clamp, injecting cannula, etc.) to localize the targeted area before incision. (AP, anteroposterior.)
Calcium Phosphate Injection Technique

The cannula should be positioned to initially treat the area of the BML that is farthest from the start point of the needle. The injectable calcium phosphate (Zimmer Knee Creations, SCP Knee Kit; Exton, PA) is then delivered to the subchondral bone under fluoroscopic guidance (Fig 9); it is critical that slow and gentle pressure is used during the injection process to allow the marrow cavity pressure to equilibrate and prevent excessive postoperative pain. If resistance is met in side-targeted cannula delivery, the cannula should be rotated to enable filling in a different direction. This strategy should be used to capture a 360° radius of calcium phosphate injection around the cannula. If a larger area is affected, then the cannula can be pulled back toward the starting point to cover a different area in parallel along the subchondral bone. A second

Fig 3. Preoperative coronal MRI of lateral tibial plateau bone marrow lesion. The fluoroscopic AP image should be referenced to the preoperative coronal MRI to ensure that the bone marrow lesion has been appropriately located. (AP, anteroposterior; MRI, magnetic resonance imaging.)

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Fig 5. The location of the symptomatic bone marrow lesion on the sagittal and coronal magnetic resonance imaging scans must be correlated on fluoroscopic imaging. (AP, anteroposterior.)

Fig 4. A perfect lateral radiograph of the knee is obtained using the cannula to localize the target area as determined by preoperative sagittal magnetic resonance imaging. The skin is marked to establish the position in the lateral dimension.

Optimizing Calcium Phosphate Injections
cortical puncture should not be made, however, because this will allow cement extravasation. Once the appropriate area has been filled with calcium phosphate, the stylus is reinserted and the cannula is left in place for 7 to 10 minutes to allow the calcium phosphate cement to harden. The cannula is then removed and the incision is inspected for any extrusion that may have occurred during the injection or subsequent cannula removal. The incision site is thoroughly irrigated and closed before case completion.

**Arthroscopy**

Knee arthroscopy is used after the subchondral injection of calcium phosphate (Fig 10), which allows removal of any calcium phosphate that may have extruded into the joint. This risk may be increased if (1) there is an insufficiency fracture present that violates the subchondral plate or (2) if the cement was injected into the distal femur, because more of the distal femur is intra-articular. Cement particles, if encountered within the joint, are brittle and prone to fragmentation if using...
an arthroscopic grasper. The use of suction alone on a large-diameter arthroscopic shaver is sufficient to remove any cement debris. Arthroscopy should also be used to treat any intraarticular pathology such as meniscal tears, chondral flaps, or loose bodies.

**Postoperative Management**

Following the procedure, patients are given crutches and instructed to be touch-down weightbearing for 4 to 5 days. After this period, they may wean off their crutches with progression to full weightbearing. Physical therapy is also initiated immediately after surgery to focus on achieving full range of motion because a loss of motion can propagate further knee stiffness and lead to deconditioning over time. Strengthening exercises are introduced once motion is achieved and an ongoing home exercise program is strongly encouraged. If concomitant procedures are performed at the time of arthroscopy, then postoperative management can be modified accordingly.

**Discussion**

The use of calcium phosphate injection for the treatment of osteoarthritis-related BML has been shown to be successful in providing short-term pain relief and to not compromise early results after total knee arthroplasty; however, differing techniques can result in variable outcomes with potential pitfalls that may hinder optimizing outcomes. We believe that this stepwise combined approach of targeted calcium phosphate injection adjacent to the subchondral bone and subsequent arthroscopy can be used to successfully address osteoarthritis-related BML in select patients. Step-by-step surgical technique instruction (Video 1) on how to target the symptomatic BML with injection of calcium phosphate is demonstrated.

Previous techniques in the literature have proposed arthroscopy evaluation before calcium phosphate injection, which will not allow for the removal of calcium phosphate that may have entered into the joint. Using postinjection arthroscopy will ensure that any calcium phosphate that enters the joint can be removed and not behave as a loose body and/or irritant to the synovial structures of the knee. Intra-articular extravasation may be higher in femoral BMLs that are treated with calcium phosphate injection because of the intracapsular area that must be traversed to access the distal femoral condyle with the cannula. In contrast, the proximal tibia capsular reflections are tightly adherent and do not typically represent a potential space for the traversing cannula to allow leakage into the joint. Care should be used to localize the affected area and avoid multiple attempts at cannula positioning within the subchondral bone because this can create channels for cement extrusion.

Although marrow edema changes can be present over a wide area of the trabecular bone, often the origin of osteoarthritis-related BML is nearest the subchondral plate where increased contact pressures and insufficiency fractures may be present. To optimally target the BML, the calcium phosphate should be injected immediately adjacent to the affected subchondral bone. Especially evident in the tibia, abnormal marrow distribution can travel distally because of gravity and depict a larger reactive area despite the symptomatic location being closer to the joint line.

Suboptimal outcomes with this operation have been seen in specific scenarios. A potential pitfall, often encountered when addressing large BMLs, is directing the calcium phosphate to the center of the BML and not abutting the subchondral plate. If the calcium phosphate does not reach the subchondral plate, then symptoms may still persist at the area of contact nearest the joint. Overfilling the BML and rapid delivery of the calcium phosphate, which can cause significant pressurization of the trabecular bone, may also lead to an exacerbation of symptoms in the immediate postoperative period. Once subjective resistance is met during slow manual delivery, the cannula should be redirected to address an untreated area. Avoiding forced delivery of the calcium phosphate may prevent additional disruption of the trabecular microarchitecture that could potentially lead to a resorption cavity. Pearls and pitfalls of this surgical approach are outlined in Table 1.

In summary, a comprehensive surgical approach for the treatment of osteoarthritis-related BML using injectable calcium phosphate is presented. This

| Table 1. Technique Pearls and Pitfalls |
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| **Pearls**                             | **Pitfalls**                                      |
| • Localization of the bone marrow lesion with fluoroscopy should be used with concurrent review of preoperative magnetic resonance imaging. | • Subchondral bone insufficiency fractures can lead to extrusion of calcium phosphate into the joint. |
| • Injection of calcium phosphate should be placed adjacent to the affected subchondral bone. | • Multiple cannula positioning attempts can lead to cement extrusion. |
| • Arthroscopy should be used after injection of calcium phosphate to remove any extruded cement. | • Forced pressurization of the calcium phosphate during delivery can lead to overfilling lesion and postoperative pain. |
| • Suction alone or a large-diameter arthroscopic shaver can be used to remove extruded cement. | |
technique highlights strategies and pitfalls in targeting the affected area of the subchondral bone and implementing the combined use of postinjection arthroscopy to address potential cement extrusion.

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