Technical Note

Intraosseous Treatment of Bone Marrow Lesions in the Knee: Surgical Technique

Jason L. Dragoo, M.D., Ankit Hirpara, B.A., Evangelia Constantine, B.S., Kyle Garrett Williams, B.S., Sydney Anne Fry, B.S., and Rahman Kandil, M.D.

Abstract: Intraosseous injections of bone marrow aspirate concentrate have shown promise in the treatment of bone marrow lesions (BMLs) in the knee. With the wide-awake limited anesthesia no tourniquet (WALANT) technique, intraosseous injections can be performed with the patient under local anesthesia in the procedure room or operating room setting. This article describes 2 techniques to access the BML of interest. The "decompression route" involves drilling through the nearest cortex, and the "biologic route" involves drilling through healthy bone to promote bleeding and the introduction of healthy biologic tissue to the BML.

The osteochondral unit plays a vital role in promoting joint health. Although treatment of articular cartilage defects in the knee has garnered attention in the past, subchondral bone pathology has been largely ignored. Focal changes in the subchondral bone, termed "bone marrow lesions" (BMLs), are associated with progression of knee osteoarthritis, degeneration, pain, and poorer clinical outcomes.[1-6] BMLs are often reversible if treatment is initiated early, and intraosseous biologic treatment is an effective therapeutic option.[7,8] This article will focus on intraosseous injection of bone marrow aspirate concentrate (BMAC) in the procedure room or operating room using 2 different image-guided techniques.

Surgical Technique

Overview

Injection of BMLs with biologics can be performed in the procedure room or operating room. The techniques are similar, but the procedure room environment includes extra considerations related to anesthesia and technical setup (Table 1). The wide-awake limited anesthesia no tourniquet (WALANT) technique has allowed physicians to perform more procedures in the outpatient setting.[9-13]

BMAC Procedure

There are 2 approaches to the iliac crest for the BMAC procedure: anterior and posterior.[14] For the anterior approach, the patient is positioned supine. The anterior superior iliac spine is prepared with ChloraPrep (chlorhexidine gluconate; BD, Franklin Lakes, NJ). The skin, subcutaneous tissues, and periosteum are anesthetized with 10 mL of 1% lidocaine. No general anesthesia is required. One should proceed only after a 5-minute period to increase the efficacy of the local anesthetic. After a small incision is made with a No. 11 blade scalpel (Bard Parker, Caledonia, MI), a small curved hemostat is used to remove tissue superficial to the crest. An 11-gauge, 11-cm Jamshidi needle (Wright Medical, Memphis, TN) pre-rinsed with 1 mg of epinephrine (1,000 U/mL) (Fresenius Kabi, Lake Zurich, IL) is placed 2 cm posterior to the anterior superior iliac spine between the inner and outer tables of the iliac crest, aiming towards the femoral head.[14] The needle is advanced through the outer cortical bone by about 1 cm. Once the needle is in the cancellous bone, the needle can be advanced in a twisting motion to a maximal depth of 4 cm in the anterior portion of the iliac crest. Once it is at its deepest point, the sharp stylet is slowly removed, a 10-mL syringe is attached, and 5 mL of bone marrow is rapidly aspirated. The Jamshidi needle is rotated, and another 5 mL is aspirated. After

From the Department of Orthopedics, University of Colorado School of Medicine, Aurora, Colorado, U.S.A. (J.L.D., A.H., E.C., K.G.W., S.A.F.); and The Orthopedic Group, Stone Springs, Dulles, Virginia, U.S.A. (R.K.).

Received September 23, 2023; accepted January 31, 2024.

Address correspondence to Jason L. Dragoo, M.D., 175 Inverness Dr W, Englewood, CO 80112, U.S.A. E-mail: j.dragoo@cuanschutz.edu

2212-6287/231406
https://doi.org/10.1016/j.eats.2024.102965

Table 1. Advantages and Disadvantages of Biologic Intraosseous Injections in Procedure Room and Operating Room

	Procedure Room	Operating Room
Advantages	• Lower cost • Faster • Less anesthesia	• Predictable pain control • Easier complication management
Disadvantages	• Potential for increased pain • Bleeding or other complications requiring management	• Higher cost • More time-consuming • More resource intensive

this, the needle is pulled back about 1 cm to a new depth, and the process is repeated with a new 10-mL syringe. This process should be repeated until a total of 60 mL is aspirated. The bone marrow aspirate is then passed for processing in a sterile fashion using a BMAC processing system.

The posterior approach follows the same steps except that the patient is positioned prone and an 11-gauge, 11-cm Jamshidi needle is placed through the outer cortex of the posterior inferior iliac spine using a vertical needle position, aiming into the inner table region, with insertion of the needle to a depth of approximately 4 cm. With the described technique, 60 mL is aspirated.

Intraosseous Biologic Injection of Knee BMLs

As shown in Figure 1, the patient is positioned supine, and a radiolucent triangle or bump is placed under the lower leg to elevate the extremity and allow for optimal anteroposterior (AP) and lateral intraoperative fluoroscopic imaging. As shown in Video 1, there are 2 different techniques that can be used to access the BML: decompression route and biologic route. The decompression route is typically chosen if only core decompression is desired or calcium phosphate cement is delivered. The biologic route can be used to promote bleeding of the adjacent vascularized bone that can enhance the local delivery of biologic factors.

Once the desired route is chosen, 10 to 15 mL of 0.5% ropivacaine (5 mg/mL) (Naropin; Fresenius Kabi) or 0.25% bupivacaine (5 mg/mL) (AuroMedics Pharma, Windsor, NJ) with 1 mg of epinephrine (1,000 U/mL) (Fresenius Kabi) added is used to provide local anesthesia. The tibial plateau and/or femoral condyle is identified using ultrasound or C-arm fluoroscopy, and the cortical entry site is identified. If the biologic route is chosen, a guide pin should be placed over the skin during fluoroscopy to ensure that the entry point will allow the proper trajectory to the BML site. A 25-gauge, 40-mm needle (BD) is then percutaneously inserted intradermally and subcutaneously, and 2 to 3 mL of local anesthetic is injected slowly. Another 3 to 4 mL is injected by angling the needle in a star manner. The analgesic is injected in a total of 5 distinct sites that circumscribe the landmark. Another 3 to 4 mL is injected as the needle is progressively inserted deeper with each piercing until contact is made with the

Fig 1. Operating room setup for intraosseous injections. The patient is lying supine with the right knee extended over a bump to allow for optimal anteroposterior and lateral intraoperative fluoroscopic imaging. The full-sized fluoroscopy unit is shown.

Table 2. Pearls and Pitfalls of Intraosseous Injections

Pearls
Mapping of the wire trajectory should be performed using fluoroscopy before incisions are made.
When approaching the subchondral bone, the surgeon should use the fluoroscopic view in which the wire appears closer to the cortex he or she is targeting (AP or lateral view).
Thrombin should be used to activate bone marrow aspirate concentrate whenever possible.
Aspiration should be performed before biologics are slowly injected in the intraosseous space.
Pitfalls
Because of the small capacity of the intraosseous space, some of the injected biologic may flow back out of the needle.
It can be difficult to accurately target lesions seen on MRI but not on fluoroscopy.
Patients may experience some pain when undergoing the WALANT technique.

AP, anteroposterior; MRI, magnetic resonance imaging; WALANT, wide-awake limited anesthesia no tourniquet.

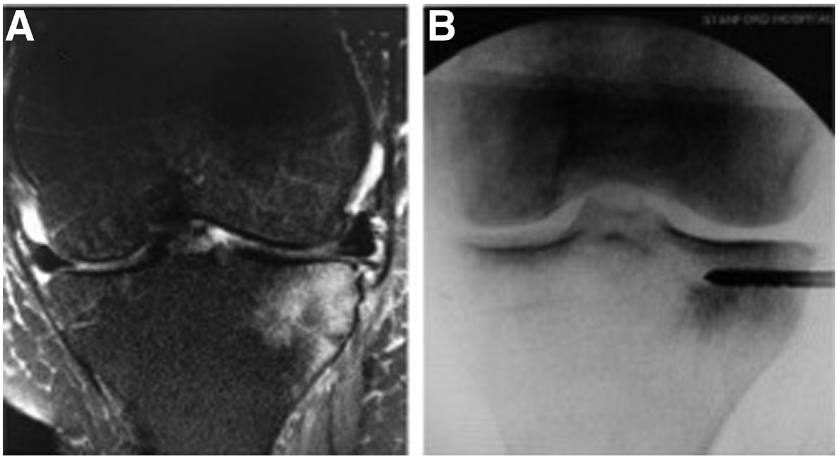

Fig 2. (A) Coronal magnetic resonance imaging shows a bone marrow lesion localized to the lateral left tibia. (B) Core decompression of the bone marrow lesion using the decompression route is performed through the nearest lateral cortex on fluoroscopy with the patient lying supine.

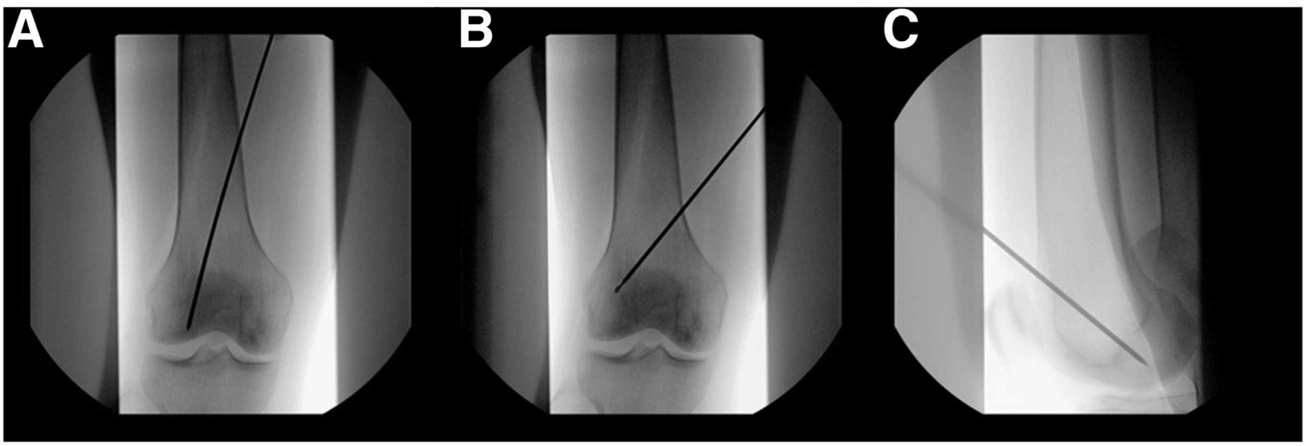

Fig 3. The proximal anterior cortex, instead of the lateral cortex, is drilled to access the bone marrow lesion seen in the posteroinferior aspect of the right femur on fluoroscopy with the patient lying supine, thereby stimulating bleeding of healthy proximal bone and introducing biologic tissue to the lesion. (A, B) Anteroposterior view of biologic route. (C) Lateral view of biologic route on fluoroscopy.

periosteum, after which an additional 2 to 5 mL is injected. During preparation of the femoral condyle location, an extra 3 mL of anesthetic solution should be applied because of increased sensitivity of the skin in this area.

At 20 minutes after application of the local anesthetic, the tip of a 15-gauge (102-mm) bone marrow harvest system (Arrow On Control; Vascular Solutions, Minneapolis, MN) is placed on the bone entry location. The trocar is fitted to a power driver (Arrow On Control)

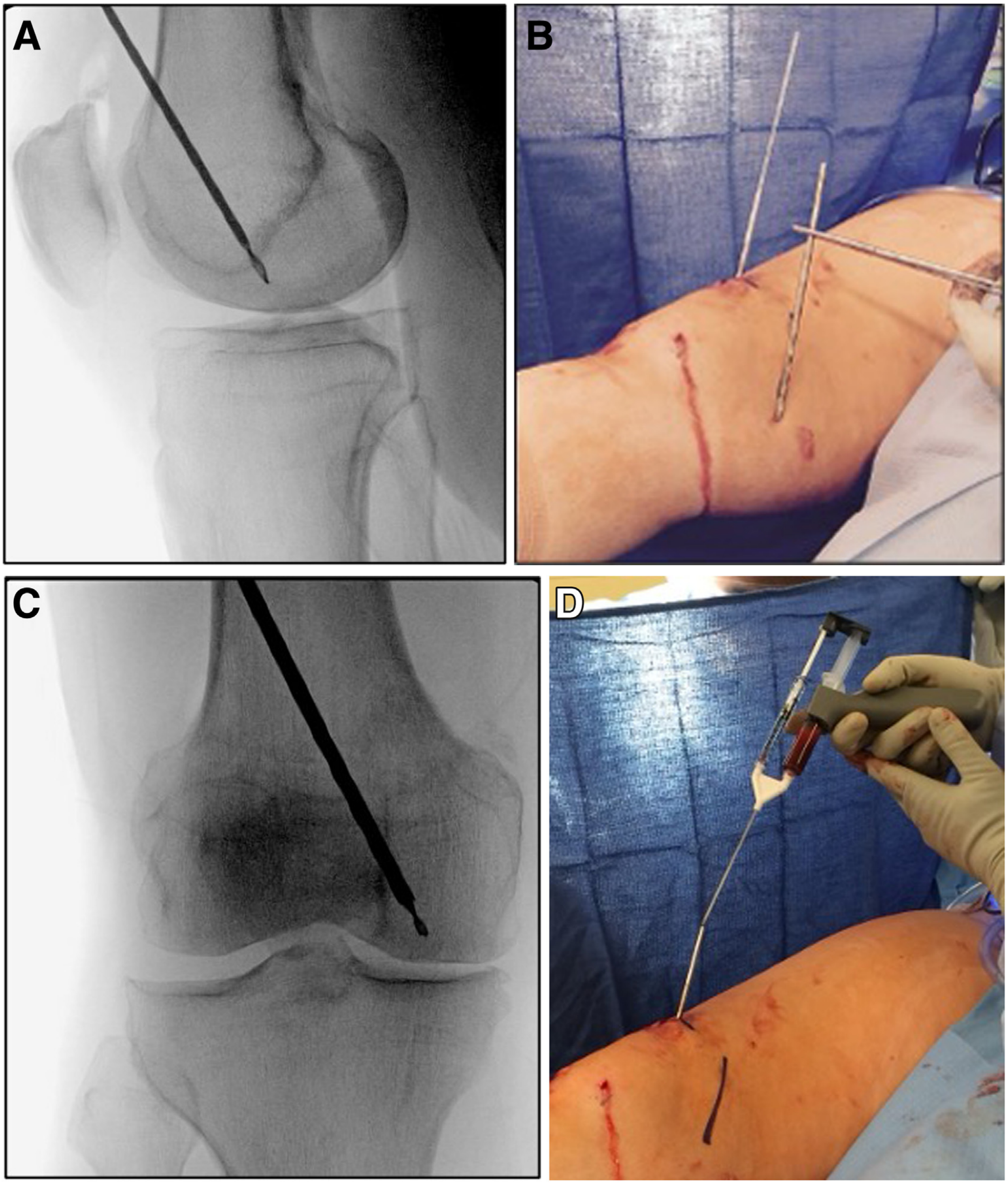

Fig 4. Step-by-step procedure using the biologic route. (A) A K-wire is placed into the area of pathologic bone on anteroposterior and lateral fluoroscopic views. (B) A 4.0-mm reamer that can fit over the guidewire is selected. (C) The reamer is placed over the K-wire and advanced under fluoroscopic visualization. (D) The guidewire is removed, and the biologic is injected into the reamer using a spinal needle.

and slowly advanced with ultrasound or C-arm imaging until the BML is reached. The trocar is slowly removed, and very slow, gentle aspiration of the local marrow is performed equal to the amount of biologic injection to be placed (Table 2). For avascular necrosis, one should consider creating many needle tracks to improve pressure decompression and marrow stimulation.

Next, 2 to 3 mL of BMAC can be slowly injected. Retention of BMAC in the intraosseous space can be improved by first activating the BMAC with 10% calcium chloride (1 g/10 mL; International Medication Systems, El Monte, CA) or thrombin (Tisseel; Baxter, Gurugram, India) per the manufacturer's recommendation. If resistance is met, the cannula can be rotated. A second cortical puncture should not be made to avoid extracortical extravasation of the biologic. Once the BMAC has been delivered, the cannula is slowly removed, and the incision is evaluated for any extravasation. Finally, the incision site is irrigated and closed with suture.

Table 3. Advantages and Disadvantages of Intraosseous Injections

Advantages	
	Injection administration involves a minimally invasive technique that can be performed with minimal sedation.
	Treatment decompresses the intraosseous pressure and stimulates vascularity and bone remodeling.
	Injections can be performed in conjunction with concurrent procedures such as arthroscopy.
Disadvantages	
	A full-sized fluoroscopy unit is required.
	If only local anesthetics are used, some patients may experience pain during the procedure.

If the biologic route is used, special considerations may be made depending on the location of the BML.[15] For distal femoral lesions, the drill pin is placed through the cortex of the distal femur approximately 2 cm proximal to the trochlea. For proximal tibial lesions, the drill pin is placed through the opposite tibial cortex of the BML; for example, if the BML is medial, the K-wire is inserted through the lateral cortex. Intra-articular extravasation may be greater in femoral BMLs because of the intracapsular area that must be traversed to access the distal femoral condyle with the cannula. In contrast, the proximal tibial capsular reflections are tightly adherent and do not typically represent a potential space for the traversing cannula to allow leakage into the joint.

Intraosseous Placement Techniques

Decompression Route. Once the area of the BML has been determined, ultrasound or fluoroscopy can be used to make skin markings representing the closest straight-line route to the BML on AP and lateral views. The K-wire (Brasseler, Savannah, GA) should be positioned perpendicular to the joint line and, at closest, about 1 cm from the articular surface (Fig 2).

By use of the 2 skin markings, a small incision is made through the skin with a No. 11 blade scalpel. A curved hemostat is used for dissection to the periosteum, after which the K-wire is drilled through the nearest cortex parallel to the joint surface as close as possible to the BML under ultrasound or fluoroscopic visualization. Then, the K-wire is reamed over with a 4-mm cannulated reamer (Arthrex, Naples, FL) to decompress the intraosseous pressure, increase blood flow, and increase potential space for a biologic. With the reamer in place, the K-wire is removed, and the biologic is injected through the reamer after it has been activated into gel form using thrombin or calcium per the manufacturer's instructions. The reamer is removed after the injection.

Biologic Route. For the biologic route, the technique involves deliberately drilling through healthy bone to promote healing of more distal pathologic bone. For example, instead of positioning the K-wire laterally for a BML in the lateral femoral condyle, it can be placed more proximally (Fig 3). Once the area of the BML has been determined, ultrasound or fluoroscopy can be used to make skin markings representing the longer trajectory of the wire to the BML on AP and lateral views. By use of the skin markings, a small incision is made through the skin. A curved hemostat is used for dissection to the periosteum, after which the K-wire is drilled to the BML under ultrasound or fluoroscopic visualization (Fig 4A). Then, the K-wire is reamed over with a 4-mm cannulated reamer (Arthrex) (Fig 4B) to decompress the intraosseous compartment, increase blood flow, and increase area for the biologic (Fig 4C). With the reamer in place, the K-wire is removed, and the biologic is injected through the reamer after it has been activated into gel form using thrombin or calcium per the manufacturer's instructions (Fig 4D). The reamer is removed after the injection.

Discussion

Performing intraosseous injections under local anesthesia has several benefits, including efficiency, reduced cost, and less exposure to anesthesia (Table 3). Intraosseous injections of biologics in the knee have also shown to be promising in the literature.[7] With BMAC specifically, Vad et al.[16] and Hernigou et al.[17] reported improvements in patient-reported outcomes and radiologic findings with no complications. However, patients may experience some pain with the procedure, and the oncologic literature may have insights into factors that affect the patient experience. The impact of various demographic factors, such as sex, age, and body mass index, on pain experienced during bone marrow procedures is still under debate.[18-20] The impact of physician experience on pain is also uncertain.[18-20]

Studies show that fear, anxiety, and emotional distress are equally as likely—or even more likely—to develop during subsequent procedures in patients who experience pain during their first bone marrow procedure.[19,21,22] As such, physicians should take the time to provide information to patients about the procedure and what exactly will be done. Sedation with oral benzodiazepines has been shown to produce retrograde amnesia along with a reduction in anxiety and pain perception.[23-25] Tramadol and nitrous oxide have also been shown to alleviate pain during bone marrow aspiration.[20,26-28]

In conclusion, this technical note describes the treatment of BMLs in the knee using intraosseous injections of biologics, such as BMAC, under local anesthesia. Injections can be performed by drilling through the cortex closest to the BML, termed the "decompression route," or by drilling through healthy bone to promote healing and introduce healthy biologic tissue to the BML, termed the "biologic route."

Disclosures

The authors report the following potential conflicts of interest of sources of funding: Jason L. Dragoo, MD is a paid consultant for Arthrex, ConMed, Zimmer Biomet, Apex Biologics, and Ampio, and receives research support from Linvatec, Smith and Nephew, Breg, Ossur, and Terumo/Globus Medical. Full ICMJE author disclosure forms are available for this article online, as supplementary material.

References

1. 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.
2. Yates PJ, Calder JD, Stranks GJ, Conn KS, Peppercorn D, Thomas NP. Early MRI diagnosis and non-surgical management of spontaneous osteonecrosis of the knee. *Knee* 2007;14:112-116.
3. Roemer FW, Frobell R, Hunter DJ, et al. MRI-detected subchondral bone marrow signal alterations of the knee joint: Terminology, imaging appearance, relevance and radiological differential diagnosis. *Osteoarthritis Cartilage* 2009;17:1115-1131.
4. Mont MA, Marker DR, Zywiel MG, Carrino JA. Osteonecrosis of the knee and related conditions. *J Am Acad Orthop Surg* 2011;19:482-494.
5. Marcacci M, Andriolo L, Kon E, Shabshin N, Filardo G. Aetiology and pathogenesis of bone marrow lesions and osteonecrosis of the knee. *EFORT Open Rev* 2016;1: 219-224.
6. Bisson LJ, Phillips P, Matthews J, et al. Association between bone marrow lesions, chondral lesions, and pain in patients without radiographic evidence of degenerative joint disease who underwent arthroscopic partial meniscectomy. *Orthop J Sports Med* 2019;7, 2325967119830381.
7. Di Matteo B, Polignano A, Onorato F, et al. Knee intraosseous injections: A systematic review of clinical evidence of different treatment alternatives. *Cartilage* 2021;13:1165s-1177s (suppl).
8. Kasik CS, Martinkovich S, Mosier B, Akhavan S. Short-term outcomes for the biologic treatment of bone marrow edema of the knee using bone marrow aspirate concentrate and injectable demineralized bone matrix. *Arthrosc Sports Med Rehabil* 2019;1:e7-e14.
9. Huang YC, Hsu CJ, Renn JH, et al. WALANT for distal radius fracture: Open reduction with plating fixation via wide-awake local anesthesia with no tourniquet. *J Orthop Surg Res* 2018;13:195.
10. Tan E, Bamberger HB, Saucedo J. Incorporating office-based surgery into your practice with WALANT. *J Hand Surg Am* 2020;45:977-981.
11. Tahir M, Chaudhry EA, Zaffar Z, et al. Fixation of distal radius fractures using wide-awake local anaesthesia with no tourniquet (WALANT) technique: A randomized control trial of a cost-effective and resource-friendly procedure. *Bone Joint Res* 2020;9:429-439.
12. Hobday D, Welman T, O'Neill N, Pahal GS. A protocol for wide awake local anaesthetic no tourniquet (WALANT) hand surgery in the context of the coronavirus disease 2019 (COVID-19) pandemic. *Surgeon* 2020;18:e67-e71.
13. Lalonde DH, Wong A. Dosage of local anesthesia in wide awake hand surgery. *J Hand Surg Am* 2013;38: 2025-2028.
14. Murphy MB, Terrazas JA, Buford DA. Bone marrow concentrate and platelet-rich plasma acquisition and preparation: Why technique matters. *Tech Reg Anesth Pain Manag* 2015;19:19-25.
15. Rebolledo BJ, Smith KM, Dragoo JL. Hitting the mark: Optimizing the use of calcium phosphate injections for the treatment of bone marrow lesions of the proximal tibia and distal femur. *Arthrosc Tech* 2018;7:e1013-e1018.
16. Vad V, Barve R, Linnell E, Harrison J. Knee osteoarthritis treated with percutaneous chondral-bone interface optimization: A pilot trial. *Surg Sci* 2016;7:1-12.
17. Hernigou P, Auregan JC, Dubory A, Flouzat-Lachaniette CH, Chevallier N, Rouard H. Subchondral stem cell therapy versus contralateral total knee arthroplasty for osteoarthritis following secondary osteonecrosis of the knee. *Int Orthop* 2018;42:2563-2571.
18. Kuball J, Schüz J, Gamm H, Weber M. Bone marrow punctures and pain. *Acute Pain* 2004;6:9-14.
19. Degen C, Christen S, Rovo A, Gratwohl A. Bone marrow examination: A prospective survey on factors associated with pain. *Ann Hematol* 2010;89:619-624.
20. Vanhelleputte P, Nijs K, Delforge M, Evers G, Vanderschueren S. Pain during bone marrow aspiration: Prevalence and prevention. *J Pain Symptom Manage* 2003;26:860-866.
21. Brunetti GA, Tendas A, Meloni E, et al. Pain and anxiety associated with bone marrow aspiration and biopsy: A prospective study on 152 Italian patients with hematological malignancies. *Ann Hematol* 2011;90:1233-1235.
22. Johnson H, Burke D, Plews C, Newell R, Parapia L. Improving the patient's experience of a bone marrow biopsy—An RCT. *J Clin Nurs* 2008;17:717-725.
23. Dunlop TJ, Deen C, Lind S, Voyle RJ, Prichard JG. Use of combined oral narcotic and benzodiazepine for control of pain associated with bone marrow examination. *South Med J* 1999;92:477-480.
24. Cerchione C, Martinelli G, Picardi M, et al. Combined oral fentanyl citrate and midazolam as premedication for bone marrow aspiration and biopsy in patients with hematological malignancies: A randomized, controlled and patient-blinded clinical trial. *J Clin Med* 2020;9:395.
25. Talamo G, Liao J, Bayerl MG, Claxton DF, Zangari M. Oral administration of analgesia and anxiolysis for pain associated with bone marrow biopsy. *Support Care Cancer* 2010;18:301-305.
26. Kanagasundaram SA, Lane LJ, Cavalletto BP, Keneally JP, Cooper MG. Efficacy and safety of nitrous oxide in alleviating pain and anxiety during painful procedures. *Arch Dis Child* 2001;84:492-495.
27. Steedman B, Watson J, Ali S, Shields ML, Patmore RD, Allsup DJ. Inhaled nitrous oxide (Entonox) as a short acting sedative during bone marrow examination. *Clin Lab Haematol* 2006;28:321-324.
28. Gudgin EJ, Besser MW, Craig JI. Entonox as a sedative for bone marrow aspiration and biopsy. *Int J Lab Hematol* 2008;30:65-67.