

Proximal Tibial Subchondral Cyst Lesion Treatment with Osteo-Core-Plasty

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21.1 Subchondral Cyst

Subchondral bone cysts are widely observed but poorly understood [1]. Patients with proximal tibial subchondral cyst had lower tibial cartilage volume and have more changes structurally compared to patients without subchondral cyst [2]. Subchondral cyst commonly coexists with bone marrow lesion (BML) especially those with Grade 3 BML or higher [3].

21.2 Epidemiology

Almost 50% of knee osteoarthritis (OA) patients have subchondral bone cysts [2, 4, 5] while only 13.6% of healthy individuals have subchondral bone cyst [2, 6]. Females had more and larger subchondral cysts in the lateral compartment than males. This finding is perhaps due to the loading effect as females also showed more valgus loading knee [7–9].

21.3 Formation

Subchondral cyst formation often occurs in osteoarthritis of the knee, more commonly in the advanced stage of osteoarthritis [2, 10, 11]. Two theories are proposed as the mechanism of cyst formation. One is the synovial breach theory [2, 12, 13] and the other one is the bony contusion theory [2, 10, 14]. Bony contusion theory explains that excessive loading or trauma can lead to trabecular microfractures, bone necrosis, and focal bone resorption, eventually resulting in cyst formation [1, 10, 15]. Synovial breach theory states that the calcified barrier between cartilage and subchondral bone is injured, allowing for fluid to seep into the subchondral bone. This eventually creates a fluid-filled cyst lesion [1, 16, 17].

The relationship between subchondral cyst and structural change of the knee is examined by one study that shows there is a correlation between alteration of the subchondral cyst size and the cartilage loss in the medial femoral condyle for a period of 2 years [2, 4].

The relationship of the BML and subchondral cyst is unclear but some studies show that it was the bone marrow lesion that was directly involved in developing subchondral cyst [2, 18–20]. Repetitive compressive load-bearing or shear loading leads to bone marrow lesion due to subchondral damage [11, 21, 22]. Some studies show that subchondral bone cysts are related to higher

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localized stress which could stimulate bone alterations or bone remodeling [1, 23].

Most likely, subchondral cyst formation is a response to altered loading distribution through the proximal tibia and also possible through joint space narrowing with disease progression [1, 24].

Subchondral cysts are usually ellipsoidal or spherical within the subchondral bone cavity and are associated with subchondral bone and cartilage degeneration of osteoarthritic knees [1, 19, 25, 26].

21.4 Location

The ratio of cyst volume to tibial volume range may be as high as 14.8% over the total proximal tibia, and up to 24.5% in the medial compartment but only up to 5.3% in the lateral compartments [1] Fig. 21.1.

The subchondral cyst volume and number were associated with the bone mineral density of medial and lateral compartments of the knee [1]. Lateral compartment subchondral cyst volume and number were associated with osteoarthritis severity, joint alignment, joint space narrowing, and gender [1]. On the other hand, in the medial

region, higher medial bone mineral density (BMD) was associated with greater cyst incidence and volume [1].

Over the total tibial region, there was a strong association that was observed between subchondral cyst incidence and alignment. This study suggests that cartilage degeneration can be associated with proportionally larger and more numerous cysts [1, 26].

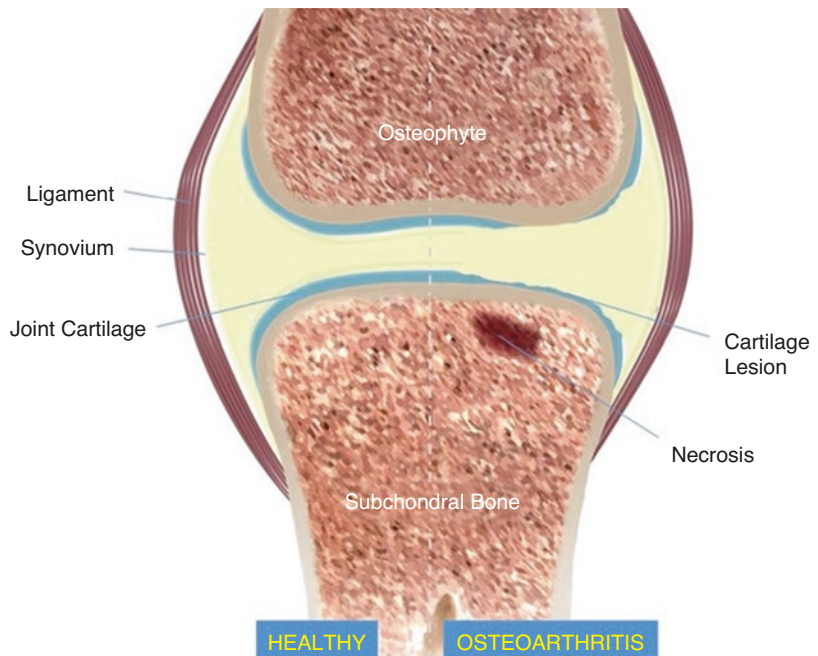
21.5 Classification

There are different ways of classifying subchondral bone cysts. They can be classified according to the following parameters, number of cysts, cyst number per total volume, cyst volume per total volume, total cyst volume, maximum cyst volume, and average cyst volume [1].

Subchondral cysts are assessed as Grade 0, without lesion; Grade 1, mild to moderate lesion; and Grade 2, severe (large) lesion [2].

Twenty-three percent to 35.7% of the patients with subchondral cysts could progress and 13% of those that have progression develop at least one or more subchondral cysts. On the other hand, subchondral cyst regression was observed

Fig. 21.1 Comparison of Healthy and Osteoarthritic Subchondral Bone; 14.8% can be seen over the proximal tibia. Courtesy of Aspire-Medical [27]



in 23.8% of the patients, of which, 14.3% experienced complete regression resolution [2].

Those with subchondral cysts had a cartilage loss rate of 9.3%. Lateral compartment regression typically has a significant lateral tibial cartilage reduction. However, greater loss of medial cartilage was noted with patients that have subchondral cyst progression [2].

21.6 Presentation

Knee Osteoarthritis is a debilitating disease, which is painful and illustrates cartilage deterioration and altered subchondral bone [1]. Recent studies show that subchondral bone has its role in progression of osteoarthritis, how it influences knee pain, and how it influences mechanical behavior of subchondral bone [1, 7, 28, 29].

Pain severity can be measured at the affected knee joint using the pain subsection of the Western Ontario McMasters Osteoarthritis Index (WOMAC) [1, 30–32], Visual Analog Scale (VAS) Scores, and Knee Injury and Arthritis Outcome Scores (KOOS) [11]. There is no correlation between cyst parameters and total WOMAC pain or nocturnal pain [1].

Osteoarthritis knee pain severity was associated with bone marrow lesions, subchondral bone attrition, effusion or synovitis, and meniscal tears, but not with subchondral bone cysts [33]. Although rare, the ganglion of the underlying subchondral bone cyst may exert pressure on the

soft tissue causing it to swell and increase pain development [34, 35].

Patients with valgus alignment may be inclined to higher cyst numbers before clinical signs of osteoarthritis, such as pain [1].

21.7 Imaging

Magnetic Resonance Imaging (MRI) can be used to distinguish a cyst from BMLs [1, 36, 37]. However, MRI cannot quantify the BMD of the patient [1]. MRI slice that yielded the greatest lesion were the cuts used to measure the subchondral cysts [2]. The extent of the subchondral cyst must be assessed on the medial and lateral tibiofemoral compartments [1].

It is unclear which specific cyst parameters, such as the number or the size, are associated with clinical symptoms, and which parameters are associated with BMD [1]. However, both medial and lateral region, cyst number, and volume were related to BMD. High cyst number per volume was also associated with high bone volume per total volume (BV/TV) [1, 25] and high trabecular thickness [1, 26]. High BMD is likely a response to higher stress, whereby local bone remodeling is affected and bone structure near the subchondral surface is changed [1, 26, 38].

A subchondral cyst was defined as a well-demarcated hypersignal, Fig. 21.2 whereas a BML could be seen as an ill-defined hypersignal.

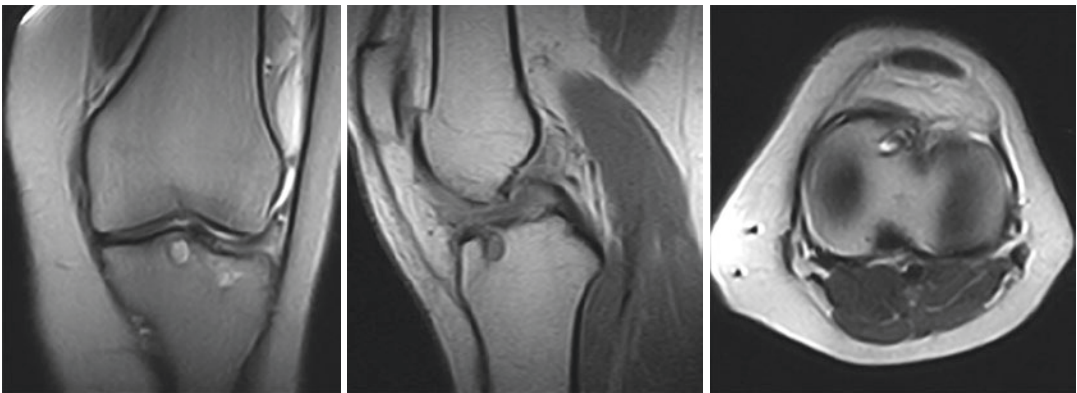


Fig. 21.2 MRI of proximal tibial subchondral cyst, left knee. Courtesy of Gobbi A

BMLs were present in 91.2% of the subregions where subchondral cysts were found [2]. Patient with a subchondral cyst had less lateral tibial cartilage volume but with greater tibial plateau bone area compared to those without subchondral bone cyst. A subchondral cyst was more likely to have large BMLs (Grade 3). On the other hand, those with BML without cyst tend to be small BML (Grade 1) [2].

Clinical quantitative computed tomography (QCT) can characterize the cyst but it is still unclear if the QCT findings are correlational with the severity of the knee pain [1]. It is reported that there are changes in bone mineral density to regions adjacent to subchondral bone cyst [1, 26]. Both MRI and QCT can offer a three-dimensional character of the cyst [1]. Kellgren-Lawrence scoring can be used to classify the osteoarthritis [1, 39].

Medial and lateral joint space widths were assessed at equal distances from the tibial spine allowing an estimation of alignment between the femoral and tibial axes. Neutral alignment was defined as $178^{\circ} \pm 2^{\circ}$ [1, 29]. Total subchondral bone cyst number and lateral cysts were associated with valgus alignment [1]. Lateral compartment is subjected to higher tibial loads in patient with valgus alignment [1, 40, 41].

21.8 Treatment Options

Treating subchondral bone defects and cartilage comprises both the biological as well as the structural component. Biological aspects of treatment include marrow stimulation techniques like K-wire drilling, microfracturing, nanofracturing, and core decompression. This treatment also includes additive therapies like autologous Platelet Rich Plasma (PRP) injections, adipose derivatives treatment, and bone marrow cell injections [27]. Structural component includes the subchondroplasty aspects such as cement injections, ACI procedures, allograft transplantation, bone marrow cell graft injections, and iliac crest bone grafting options [27]. Fig. 21.3.

Bone marrow stimulation technique such as microfracture led to the formation of subchondral cyst (63% of cases). Drilling prompted significant changes in almost all parameters of the architecture of the subchondral bone. It weakens the micro-architecture of the subchondral bone plate and the subarticular spongiosa. Entire osteochondral unit is altered after drilling [42].

There are a lot of treatment options in the market depending on the patient’s condition. This chapter will focus on Osteo-Core-Plasty as a viable option in treating subchondral bone cyst.

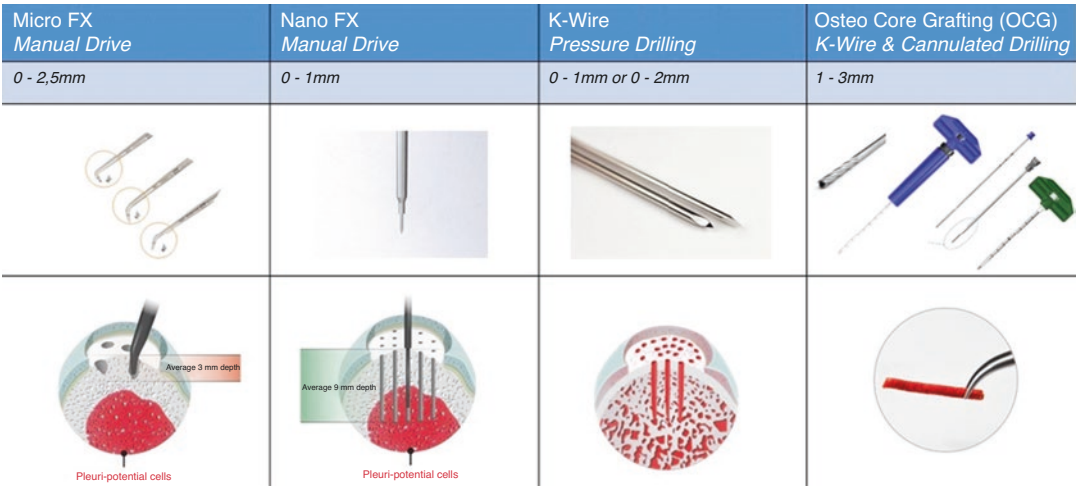


Fig. 21.3 Comparison of Different Subchondral Bone Treatment with their corresponding hole size in drilling and instruments used. Courtesy by Aspire-Medical [27]

21.9 Osteo-Core-Plasty

Osteo-Core-Plasty (Marrow Cellution™) is a minimally invasive subchondral bone augmentation procedure that provides both biologic and structural components to provide an optimized environment for regeneration. It is a fluoroscopic guided, minimally invasive, autologous, biologic procedure that allows necrotic bone segment resection and transplant living, live, intact bone segments that have the capabilities to reincorporate naturally without foreign body implantation [27].

It is an approach that could potentially overcome the issue of centrifugation techniques wherein there is an increased level of peripheral blood nucleated cells which contain very few stem or progenitor cells [43]. It uses multiple small volume draws (1 mL) from a single puncture that utilizes lateral flow from multiple sites near the inner cortical bone space in bone marrow (SSLM method) [43]. It is identified that this anatomical location contains a high number of bone marrow stem or progenitor cells [43–46].

Osteo-Core-Plasty starts with bone marrow aspiration process. Figure 21.4 All the materials

and instruments are prepared. Aseptic technique is applied over the iliac crest and operative site. First is to heparinize all kit components using 2,000 units/mL heparin. Then, Introducer Needle with sharp stylet is inserted just past cortex into the medullary space. Sharp stylet is then removed. Syringe is attached and 1 mL marrow is aspirated to ensure proper positioning of the needle tip. Then, the syringe is removed. Blunt Stylet is inserted and locked. Introducer Needle may now be advanced to the desired depth. Then, Guide Grip is now rotated to skin level. Blunt Stylet is then removed. Next, the Aspiration Cannula is inserted and secured. Then, syringe is attached and 1 mL marrow is aspirated. Then, Guide Grip is held at the handle and rotated 360° counter-clockwise then another 1 mL is aspirated. Guide Grip could be rotated as needed and could be reassembled for additional puncture sites [27].

Application could be done arthroscopically or open access method. Arthroscopic method is done with fluoroscopic guidance. Necrotic Tissue Zone is identified. K-wire is then inserted to the target zone and cannulated drill is inserted over the K-Wire. K-Wire and necrotic bone core are then removed. Extraction/Delivery Tool contain-

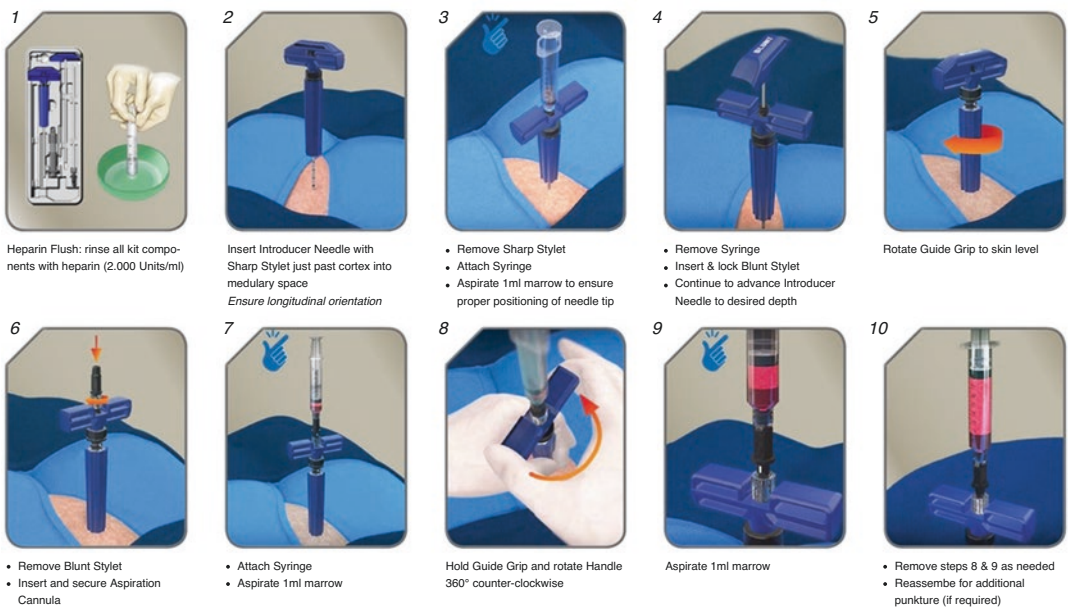


Fig. 21.4 Steps in Marrow Cellution™ Bone Marrow Aspiration Process. Courtesy by Aspire-Medical [27]

ing Marrow Cellution Bone Core Graft. Next, Probe is inserted to push bone core graft to target zone position. Lastly, Marrow Cellution™ is injected as liquid bone graft [27] Fig. 21.5.

Open technique is also done with fluoroscopic guidance wherein the necrotic tissue zone is identified. Then, cartilage bed is now debrided. After debridement, cannulated drill is inserted to required depth. Necrotic core is

removed. Extraction/Delivery Tool containing Marrow Cellution™ Bone Core Graft is then inserted. Then Probe is used to push Bone Core Graft to Distal Position. Then, Marrow Cellution™ Liquid Bone Graft is injected. Then the Marrow Cellution™ Saturated Matrix Scaffold Membrane is applied. Finally, Fibrin Glue is applied to seal the membrane [27] Fig. 21.6.

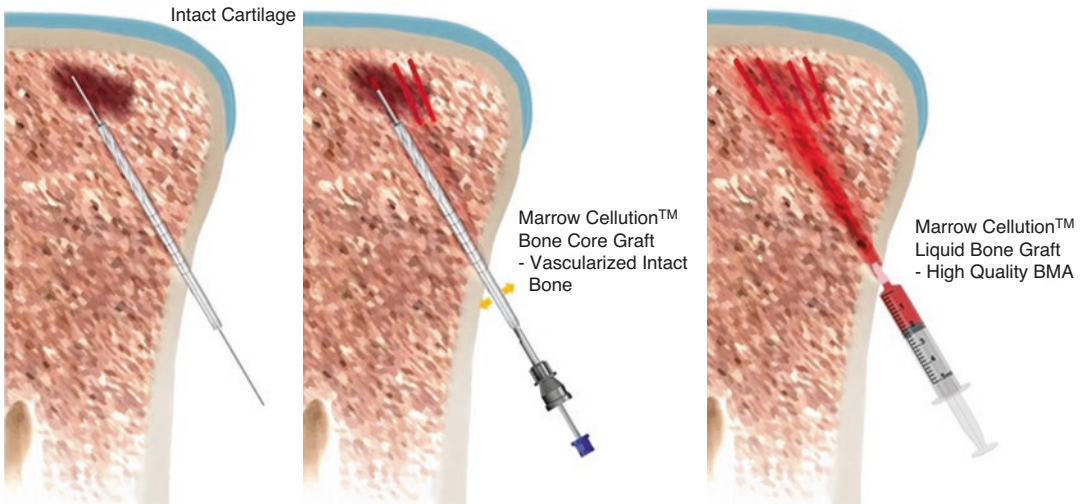


Fig. 21.5 Osteo-Core-Plasty for Intact Cartilage: Arthroscopic Application Steps. Courtesy by Aspire-Medical [27]

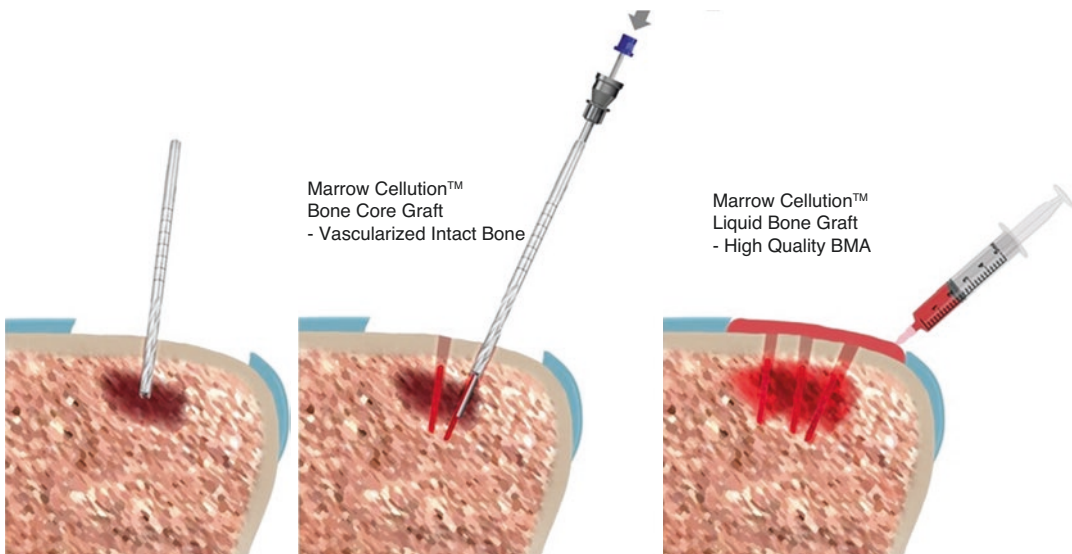


Fig. 21.6 Osteo-Core-Plasty: Open Access Surgical Procedure Steps. Courtesy by Aspire-Medical [27]

	Marrow Cellution™	Harvest BMAC®
Aspiration Volume	7-10 mL	60 mL
Final Volume	7-10 mL (No change)	7 mL
Aspiration Sites	1	3
Aspiration Time	1-2 Minutes	3-5 Minutes
Manipulated off Sterile Field	NO	YES
Processing Time	0 Minutes	17 Minutes
CFU-f/million TNC	51.89	12.37
Avg. CFU-f Concentration	1697.8 per mL	835 per mL

Fig. 21.7 Table of Comparison of Osteo-Core-Plasty using Marrow Cellution™ Technique versus Centrifugation Technique using Harvest BMAC®. Courtesy by Aspire-Medical [47]

Studies show that bone marrow samples containing a relatively high CFU-fs/mL and CD34+/mL can be attained without the need for centrifugation using the Marrow Cellution™ system. The level of CFU-fs/mL was significantly higher in the Osteo-Core-Plasty compared to BMACs in side-by-side comparison from the same patients using the contralateral iliac crest [43]. Another study showed that the Osteo-Core-Plasty had over twice as many fibroblast-like colony forming units (CFU-f) and only half as many nucleated cells compared to centrifugation techniques [47] Fig. 21.7. Moreover, the Osteo-Core-Plasty showed the same numbers of CD34+ and CD117+ cells compared to centrifugation techniques [43].

There are several benefits of Osteo-Core-Plasty. It allows the clinician to retain the product entirely on the sterile area rather than necessitating the product to leave the sterile area for centrifugation and reenter the sterile area for administration to the patient, decreases procedural expenses, and maintains all the cells and growth factors obtained during aspiration [48]. Users of this technique reported that another

advantage is the ability to advance into and retreat from the marrow area in both precise and controlled manner [48]. This technique produced a higher quality aspirate with the necessity to aspirate only the volume needed for regeneration treatment [48].

21.10 Take Home Message

There is still no gold standard treatment protocol in treating subchondral bone cysts. Different treatment modalities have been tested in the hope that they might reduce pain and stop the progression of the disease.

Subchondral cysts may not directly cause the pain [33] but they are associated with subchondral bone and cartilage degeneration which further causes painful osteoarthritic knees [1, 19, 25, 26].

Advancement in MRI and early diagnosis of osteoarthritis has opened a broader knowledge about the significance of subchondral bone. Long-term results using bone marrow aspirate concentrate showed promising clinical outcomes

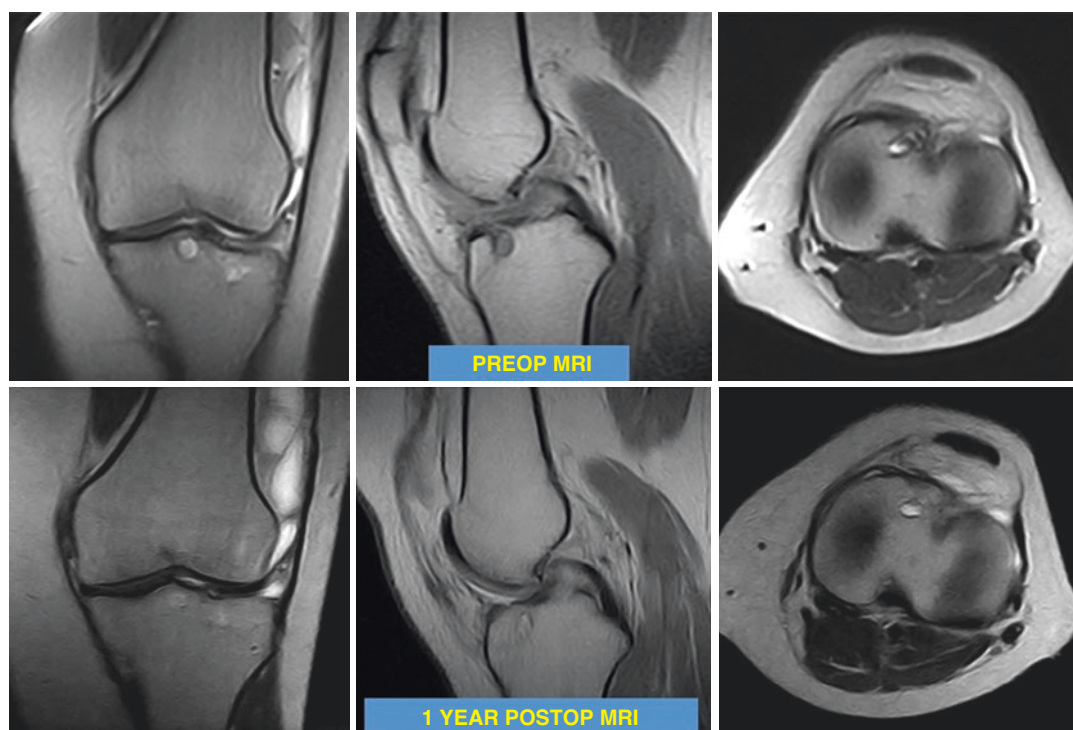


Fig. 21.8 Comparison of preoperative and postoperative Osteo-Core-Plasty MRI showing improvement manifested as increased hypointensity over the proximal tibial subchondral cyst. Courtesy of Gobbi A

in repair of cartilage lesions [49, 50]. Similar biologic treatment for subchondral cyst can aid in the healing response of such lesions.

Osteo-Core-Plasty is a viable option in treating proximal tibia subchondral cyst by reducing pain over the affected area, returning to activity early [11, 51] and improved MRI imaging showing increased hypointensity over the subchondral cyst [52, 53]. Fig. 21.8

There is still a need for high-quality RCTs studies and systematic reviews in the future to further improve treatment strategy in preventing or treating subchondral bone cyst manifested as a late stage of osteoarthritis.

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