

Osteo-Core-Plasty technique for the treatment of a proximal tibial subchondral cystic lesion

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INTRODUCTION

Subchondral bone cysts are widely observed but poorly understood.¹ Patients with proximal tibial subchondral cyst had lower tibial cartilage volume and more structural changes than patients without a subchondral cyst.² Subchondral cysts commonly coexist with bone marrow lesions (BMLs), especially those with Grade 3 BML or higher.³

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

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 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 fluid to seep into the subchondral bone. This eventually creates a fluid-filled cyst lesion.^{1,16,17}

The relationship between the 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 two years.^{2,4}

The relationship between the BML and the subchondral cyst is unclear. Still, some studies show that the bone marrow lesion was directly involved in developing the subchondral cyst.^{2,18-20} Repetitive compressive load-bearing or shear loading leads to bone marrow lesions due to subchondral damage.^{11,21,22} Some studies show that subchondral bone cysts are related to higher localized stress, stimulating bone alterations or bone remodeling.^{1,23}

Subchondral cyst formation is most likely a response to altered loading distribution through the proximal tibia and 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}

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. 1)

The subchondral cyst volume and number were associated with the knee's bone mineral density of medial and lateral compartments.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, higher medial bone mineral density (BMD) was associated with greater cyst incidence and volume in the medial region.¹

Over the total tibial region, a strong association 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}

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

23% to 35.7% of the patients with subchondral cysts could progress, and 13% of those with progression develop at least one or more subchondral cysts. On the other hand, subchondral cyst regression was observed 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

Presentation

Knee Osteoarthritis is a debilitating disease, which is painful and illustrates cartilage deterioration and altered

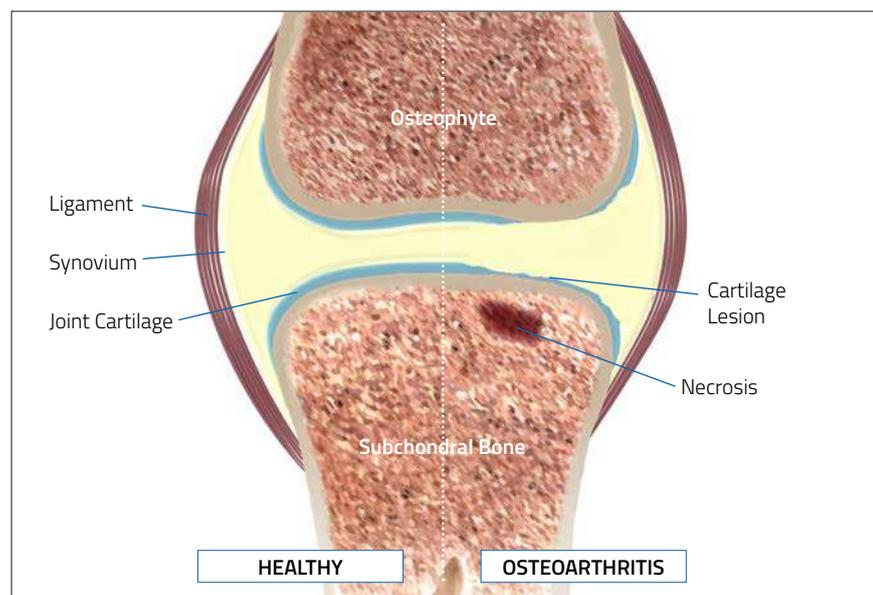


Figure 1: Comparison of Healthy and Osteoarthritic Subchondral Bone. 14.8% can be seen over the proximal tibia. Courtesy of Aspire-Medical⁴¹

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 bone.¹ Recent studies show that subchondral bone has a role in the progression of osteoarthritis, how it influences knee pain, and how it influences the mechanical behavior of subchondral bone.^{1, 7, 27, 28}

Pain severity can be measured at the affected knee joint using the pain subsection of the Western Ontario McMasters Osteoarthritis Index (WOMAC)^{1, 29-31}, 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 subchondral bone cysts.³² 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.^{33, 34} Patients with valgus alignment may be inclined to higher cyst numbers before clinical signs of osteoarthritis, such as pain.¹

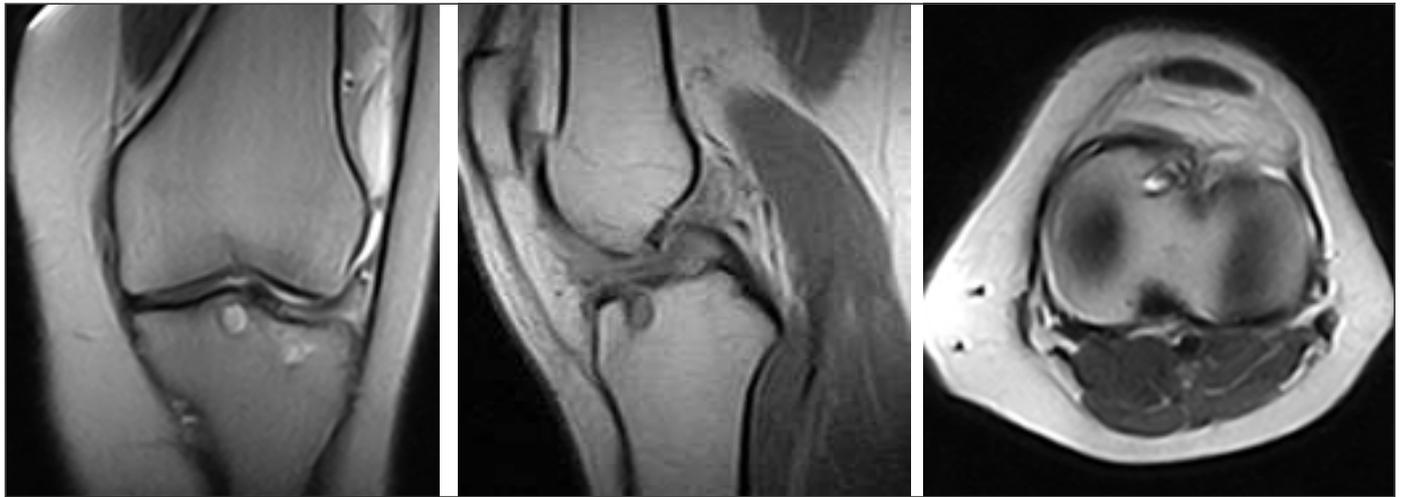


Figure 2: MRI of proximal tibial subchondral cyst, left knee. Courtesy of Gobbi, A.

Imaging

Magnetic Resonance Imaging (MRI) can be used to distinguish a cyst from BML's.^{1, 35, 36} However, MRI cannot quantify the BMD of the patient.¹ MRI slices 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, 37}

A subchondral cyst was defined as a well-demarcated hyper signal (Fig. 2) whereas a BML could be seen as an ill-defined hyper signal. BML's were present in 91.2% of the subregions where subchondral cysts were found.² Patients with a subchondral cyst had less lateral tibial cartilage volume but with greater tibial plateau bone area than those without subchondral bone cyst. A subchondral cyst was more likely to have large BML's (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 the subchondral bone cyst.^{1, 26} Both MRI and QCT can offer the three-dimensional character of the cyst.¹ Kellgren-Lawrence scoring can be used to classify osteoarthritis.^{1, 38}

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, 28} Total subchondral bone cyst number and lateral cysts were associated with valgus alignment.¹ Lateral compartment is subjected to higher tibial loads in a patient with valgus alignment.^{1, 39, 40}

Treatment Options

Knee Treating subchondral bone defects and cartilage comprises both the biological as well as a 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.⁴¹ 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.⁴¹ (Fig. 3)

Bone marrow stimulation techniques such as microfracture led to subchondral cyst formation (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

Micro FX Manual Drive	Nano FX Manual Drive	K-Wire Pressure Drilling	Osteo Core Grafting (OCG) K-Wire & Cannulated Drilling
0 - 2,5mm	0 - 1mm	0 - 1mm or 0 - 2mm	1 - 3mm

Figure 3: Comparison of different subchondral bone treatments with their corresponding hole size in drilling and instruments used.

subarticular spongiosa. The 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.

Osteo-Core-Plasty

Osteo-Core-Plasty (Marrow Cellution™) is a minimally invasive subchondral bone augmentation procedure that provides biologic and structural components to provide an optimized environment for regeneration. It is a fluoroscopic

guided, minimally invasive, autologous, biologic approach that allows necrotic bone segment resection and transplant living, live, intact bone segments that have the capabilities to reincorporate naturally without foreign body implantation.⁴¹

It is an approach that could potentially overcome centrifugation techniques wherein there is an increased level of peripheral blood nucleated cells containing very few stem or progenitor cells.⁴³ It uses multiple small volumes draws (1mL) from a single puncture that utilizes lateral flow from multiple sites near the inner cortical bone space

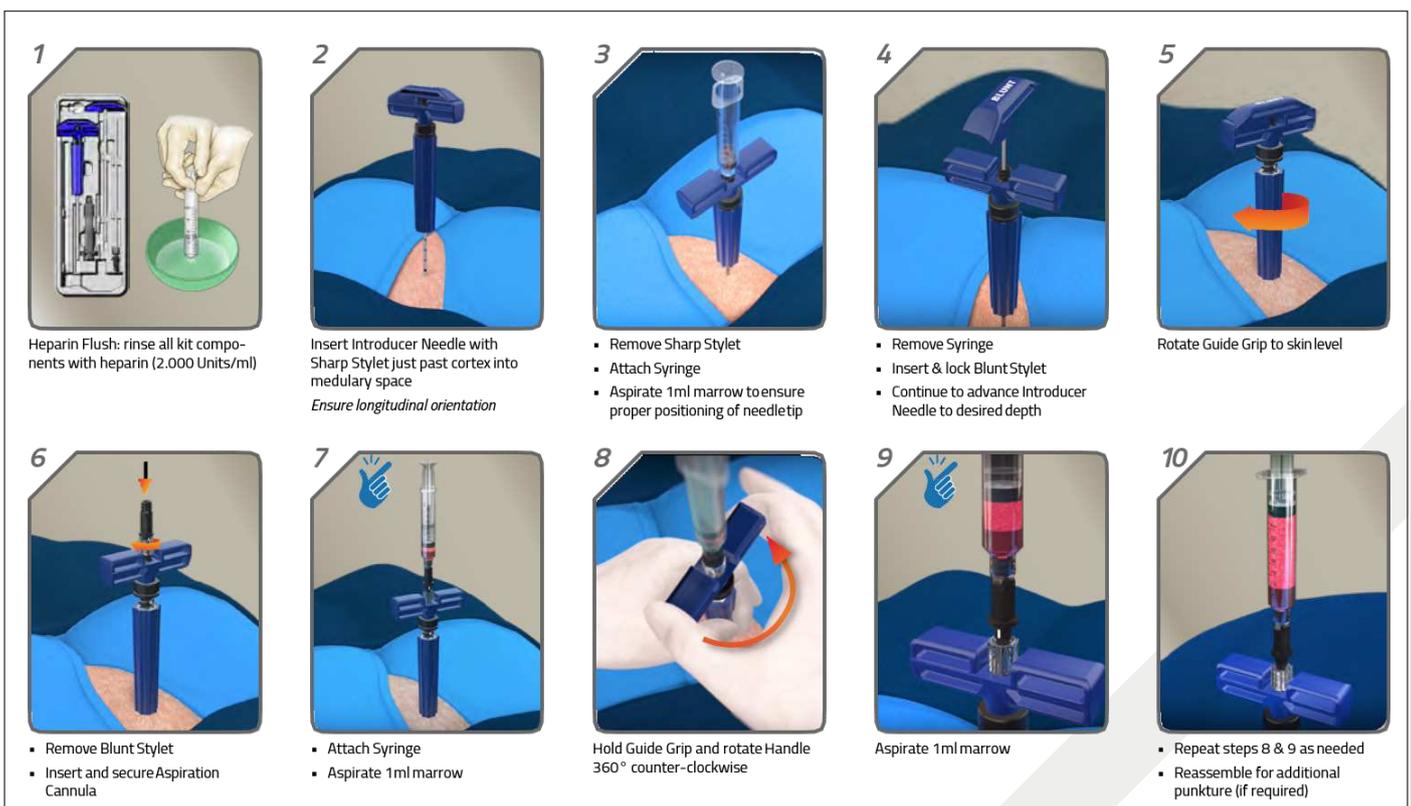


Figure 4: Steps in Marrow Cellution™ Bone Marrow Aspiration Process. Courtesy of Aspire-Medical⁴¹

in bone marrow (SSLM method).⁴³ It is identified that this anatomical location contains many bone marrow stem or progenitor cells.⁴³⁻⁴⁶

Osteo-Core-Plasty starts with the bone marrow aspiration process. (Fig. 4) All the materials and instruments are prepared. Aseptic technique is applied over the iliac crest and operative site. The first is to heparinize all kit components using 2.000 units/mL heparin.

1mL marrow is aspirated. Then, Guide Grip is held at the handle and rotated 360° counterclockwise; then another 1mL is aspirated. Guide Grip could be turned as needed and could be reassembled for additional puncture sites.⁴¹

The application could be done arthroscopically or open access method. The arthroscopic technique is done with fluoroscopic guidance. Necrotic Tissue Zone is identified. K-wire is then inserted into the target zone, and cannulated drill is inserted over the K-Wire. K-Wire and necrotic bone core are then removed. Extraction/Delivery Tool containing Marrow Cellution™ Bone Core Graft. Next, a Probe is inserted to push the bone core graft to the target zone position. Lastly, Marrow Cellution™ is injected as a liquid bone graft.⁴¹ (Fig. 5)

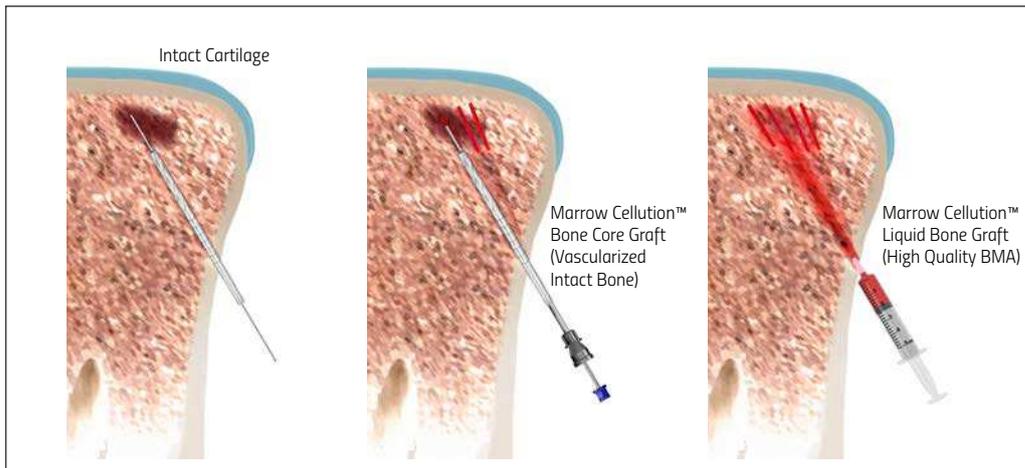


Figure 5: Osteo-Core-Plasty for Intact Cartilage: Arthroscopic Application Steps. Courtesy of Aspire-Medical ⁴¹

The open technique is also done with fluoroscopic guidance wherein the necrotic tissue zone is identified. Then, the cartilage bed is now debrided. After debridement, the cannulated drill is inserted to the required depth. The 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 used to seal the membrane.⁴¹ (Fig. 6)

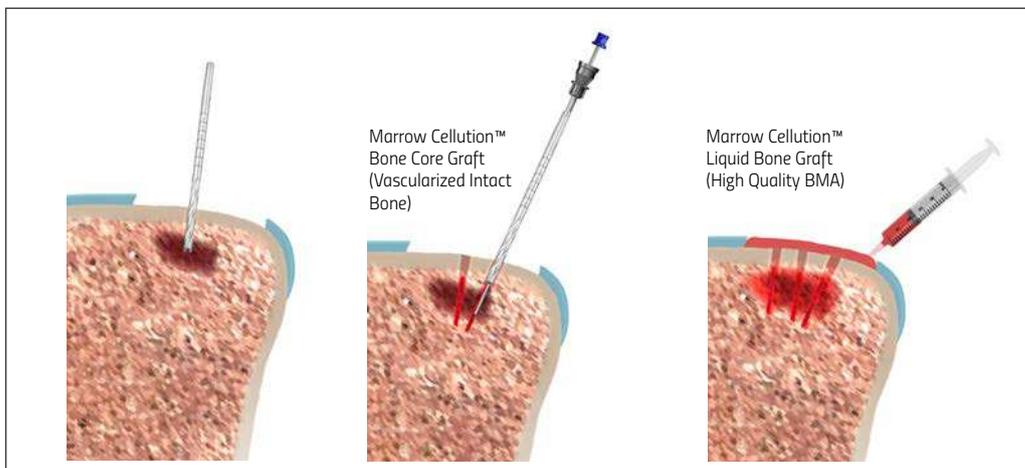


Figure 6: Osteo-Core-Plasty: Open Access Surgical Procedure Steps. Courtesy of Aspire-Medical ⁴¹

Then, Introducer Needle with a sharp stylet is inserted just past the cortex into the medullary space. A sharp stylet is then removed. The syringe is attached, and 1mL 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, the syringe is attached, and

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 a 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 colonies forming units (CFU-f) and only half as many

nucleated cells compared to centrifugation techniques.⁴⁷ (Fig. 7) Moreover, the Osteo-Core-Plasty showed the same numbers of CD34+ and CD117+ cells compared to centrifugation techniques.⁴³

	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 Min.	3-5 Min.
Manipulated off Sterile Field	NO	YES
Processing Time	0 Min.	17 Min.
CFU-f/million TNC	51.89	12.37
Avg. CFU-f Concentration	1,697.8 per mL	835 per mL

Figure 7: Comparison of Osteo-Core-Plasty using Marrow Cellution™ Technique vs. Centrifugation Technique using Harvest BMAC®.⁴⁷

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, re-enter the sterile area for administration to the patient, decrease procedural expenses, and maintain 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 a 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

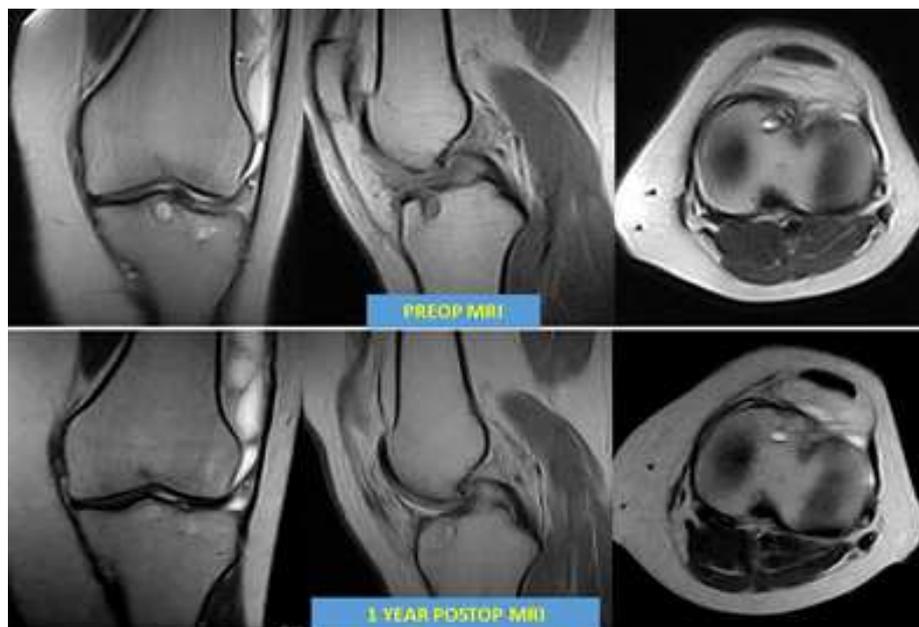


Figure 8: Comparison of pre-operative and post-operative Osteo-Core-Plasty MRI showing improvement manifested as increased hypointensity over the proximal tibial subchondral cyst.

Courtesy of Gobbi, A.

Take-Home Message

- There is still no gold standard treatment protocol in treating subchondral bone cysts. Different treatment modalities have been tested, hoping that they might reduce pain and stop the progression of the disease.
- Subchondral cysts may not directly cause the pain³², but they are associated with subchondral bone and cartilage degeneration which furtherly 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 in the repair of cartilage lesions.^{49, 50} Similar biologic treatment for subchondral cyst can aid in the healing response of such lesion.
- 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 hypointensity over the subchondral cyst.^{52, 53}(Fig. 8)

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