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Research Article

Drill And Fill: The Pioneering Subchondroplasty for Ankle Subchondral Cystic Lesion; A Multi-Case Analysis

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Abstract

Subchondral cyst of the talus and tibial plafond has been the area of interest in foot and ankle surgery for many years. Subchondroplasty (Zimmer Inc., Warsaw, Indiana) is a novel technique used to treat large subchondral cyst associated with bone marrow edema under fluoroscopic guidance. The procedure involves percutaneous injection of flowable nanocrystalline calcium phosphate synthetic bone graft, AccuFill (Zimmer Inc., Warsaw, Indiana) Bone Substitute Material into the cancellous trabeculae of the subchondral bone. We evaluated six patients with symptomatic cystic lesion of the ankle with a median of 43.5 weeks (range 17-119) follow up post procedure. The cohort consisted of 4 men and 2 women with mean age at surgery of 62 years old (SD: 12, range 45-81). The mean size of the lesion was 0.99 cm3 (SD: 0.74, range 0.38-2.28).

Post operatively, the fill recorded a mean of 0.62 cm3 (SD: 0.46, range 0.23-1.36), which is equivalent to a mean of 63.5% (SD: 9.52, range 51.5-75) fill compared to pre operative size of the lesions. The Manchester-Oxford Foot Questionnaire index also showed marked improvement in all 6 patients. From the pre operative mean of 73.5% (SD : 12.2, range 56.3-84.4), it fell to a mean of 24.7% (SD : 7.03, range 14-35) post operatively. Subchondroplasty offers promising potential as a viable treatment option for addressing ankle-related subchondral bone defects, offering pain relief and improved joint function. It is definitely an alternative to more invasive surgical interventions, may reduce patient morbidity and shorten recovery times.

Introduction

Large subchondral cyst of the ankle region has been the subject of increasing interest for the past few years. These lesions occur in the talus and tibial plafond, generally secondary to single or multiple traumatic events. As a result, there are varying degrees of partial or complete detachment of the chondral fragment with or without displacement. Majority of the cyst involves the talus while approximately 2.6% of isolated cyst of the ankle occur in the distal tibial plafond, equivalent to 20:1 ratio in the literature. (10)

Subchondral cyst formation is often the sequelae of the injury to the cartilage. Defect in the cartilage allows a unidirectional invasion of fluid from the joint into the underlying subchondral bone. Over time, osteolysis and subchondral cyst formation occur. The increase in fluid pressure results in increasing pain due to the well-innervated subchondral bone. (27) Subchondral cysts have less favorable results with standard arthroscopic techniques. (19) Additional surgical procedures include retrograde drilling, trans-malleolar drilling, filling of the bony defect with autogenous cancellous bone graft, autologous chondrocyte implantation, matrix-associated chondrocyte implantation, osteochondral autograft transfer system (OATS) and autologous matrix-induced chondrogenesis. (3,21)

Generally, lesions < 1.0 cm2 can be treated with excision and curettage while larger lesions require grafting of the void. A point of paramount significance, the status of the articular surface needs to be assessed by utilizing standard arthroscopic techniques. For cases in which the cartilage cap remains intact, retrograde drilling remains the go-to procedure. It causes bleeding and an inflammatory response to stimulate new bone formation at the lesion site while avoiding damage to the healthy cartilage. This technique can be also performed along with grafting or bone marrow aspirate to assist with filling of the void and stimulating growth respectively. (15)

Subchondroplasty (Zimmer Inc., Warsaw, Indiana) is a novel technique used to treat large subchondral cyst associated with bone marrow edema under fluoroscopic guidance. The procedure involves percutaneous injection of flowable nanocrystalline calcium phosphate synthetic bone graft, AccuFill (Zimmer Inc., Warsaw, Indiana) Bone Substitute Material (BSM) into the cancellous trabeculae of the subchondral bone. (26)

It is hypothesized that the calcium phosphate improves the structural integrity and biomechanical strength of pathologic subchondral bone without damaging the existing bone scaffold. (23) In addition, the highly porous osteoconductive nature of this material allows for eventual ingrowth of healthy cancellous bone

capable of weight bearing. (16)

Previous studies on the application of flowable calcium phosphate (CaP) for treating bone marrow lesions (BML) has predominantly focused on knee. (1,5,7) However, due to the necessity for joint-conserving procedures in ankle osteoarthritis and the management of symptomatic BML, there has been a growing interest in exploring its use in the foot and ankle.

Early reports by Miller et al. presented two cases of subchondroplasty for talar BML. At a 10-month follow-up, both patients reported minimal subjective pain with no activity restrictions. (22) In 2018, Chan et al. conducted a retrospective cohort study involving 11 patients with symptomatic talar osteochondral defects treated using subchondroplasty with bone marrow aspirate concentrate (BMAC) injection. The mean size of the talar defects in this cohort was 1.3 cm x 1.4 cm. Subjective outcomes, including visual analog pain scale and Foot and Ankle Outcome Score, significantly improved from preoperative baseline to the final one-year follow up. All patients returned to full activity within three to nine weeks postoperatively. (6)

Despite the growing interest in subchondroplasty for foot and ankle disorders, there remains a notable gap in the literature regarding the subchondroplasty technique and its outcomes in this anatomical region. As such, this paper presents a compelling case series encompassing six patients who underwent subchondroplasty for distinct foot and ankle pathologies. Through this detailed description, we aim to share our experience on the efficacy, safety and clinical outcomes of subchondroplasty, while identifying factors that influence its success.

Materials and methods

From March 2015 to April 2021, six patients with symptomatic cystic lesion of the ankle have been included in this study. The cohort consisted of 4 men and 2 women with mean age at surgery of 62 years old (SD: 12, range 45-81).

Two patients had undergone total ankle replacement (TAR) prior to developing the lesion, one had a TAR performed at 186 weeks after the subchondroplasty procedure. Another three had previous intervention (injection) to address the symptomatic subchondral defect before the definitive subchondroplasty. As for the anatomical distribution of the lesions, five patients had defect on the talus while one was on tibial plafond. The preoperative size of the cyst and post operative fill of the AccuFill BSM were measured tridimensionally, expressed as ellipsoid volumes ($D1 \times D2 \times D3 \times \pi/6$). The percentage of the fill was also

calculated. The Manchester-Oxford Foot Questionnaire (MOXFQ) was administered pre and post operatively at the latest follow up.

The subchondroplasty procedure was done with the patient in the supine position. A noninvasive ankle distraction was used. In most cases, ankle arthroscopy with the standard anteromedial and anterolateral portals, performed first to evaluate the integrity of the articular cartilage and to address any intra-articular pathology. The unstable cartilage and joint synovitic tissue were then debrided using a shaver. With the preoperative MRI or CT as reference, the drill bit and cannula were triangulated into the lesion, confirmed with antero-posterior, oblique and lateral flouroscopy views. It is paramount to avoid multiple drill attempts as these may lead to extravasation. A syringe filled with the AccuFill BSM is luer-locked with the cannula and injected into the defect under fluoroscopic imaging.

Care was taken to not over-pressurize the bone with the injection. Arthroscopy was performed throughout the procedure to ensure no intra-articular graft extravasation. Following a time lapse of 4-5 minutes after the AccuFill BSM injection, the trocar was reinserted into the injection cannula before all instrumentation safely removed.

This was performed as a day case procedure, and all the patients returned home on the same day. Following surgery, the patients were advised not to bear weight on the operated limb for 4 weeks and provided with walking boot for an additional 4 weeks. This is to allow adequate time for AccuFill BSM curing. Computed Tomography (CT) scans were routinely performed 6 months post procedure for all the patients.

Results

The mean size of the lesion was 0.99 cm3 (SD: 0.74, range 0.38-2.28). The cohort underwent surgery at a median of 85 weeks (range 16-243) from the time of first presentation at the clinic. (one patient had a missing data).

Post operatively, the fill recorded a mean of 0.62 cm3 (SD: 0.46, range 0.23-1.36), which is equivalent to a mean of 63.5% (SD: 9.52, range 51.5-75) fill compared to pre operative size of the lesions. The MOXFQ index also showed marked improvement in all 6 patients. From the pre operative mean of 73.5% (SD : 12.2, range 56.3-84.4), it fell to a mean of 24.7% (SD : 7.03, range 14-35) post operatively. These latter scores were taken at the final follow up, a median of 43.5 weeks (range 17-119) from the date of the subchondroplasty procedure. (Table 1)

No complications noted intra operatively or post operatively for all of the study patients. The one patient (Patient 4) who underwent TAR after subchondroplasty did not require any additional augmented fixation, further highlighting the efficacy of subchondroplasty in reducing the size of the cystic lesion and restoring bone stock.

No.	Age	Diagnosis	Defect size (cm^3)	Time to SCP (weeks)	AccuFill (cm^3)	AccuFill (%)	Pre operative MOXFQ	Post operative MOXFQ	Follow up post SCP (weeks)
1	60	OLT	0.38	45	0.23	62.9	84.4	25	37
2	67	Post TAR (OLT)	2.28	137	1.36	59.8	82.8	14	119
3	81	Post TAR (OCLTP)	1.35	243	1.00	74.5	79.6	23.4	17
4	61	OLT	0.4	85	0.3	75	78.1	21.9	22
5	45	OLT	1.02	16	0.52	51.5	56.3	35	51
6	55	OLT	0.53	N/A	0.3	57	60	28.8	50

Table 1 : Summary of the outcomes measured in this case series

Abbreviation: *OLT = osteochondral lesion of talus, TAR = total ankle replacement, OCLTP = osteochondral lesion of tibial plafond, SCP = subchondroplasty, MOXFQ = Manchester-Oxford Foot Questionnaire*

Discussion

Traditionally, subchondroplasty has been extensively applied in larger weight bearing joints, such as the knee, where it has demonstrated encouraging results in addressing osteoarthritis-related subchondral bone defects.(1,4,5,7,17) However, its application in the foot and ankle has been relatively underexplored until recent times.(9) The intricate anatomy and unique biomechanics of the foot and ankle present distinct challenges, requiring a specialized approach to maximize the benefits of subchondroplasty in this anatomical region. Subchondral cyst of the talus and tibial plafond, bone marrow edema of the subtalar joint are among the pathologies that can significantly benefit from this minimally invasive procedure.(2,18,24)

This multi-case analysis showcases two prominent instances of ankle cysts: the first being a degenerative cyst affecting the native joint, and the second, a peri-prosthetic cyst. The latter may signify the evolution of a previously unnoticed small cyst prior to fixation or emerge due to implant material-induced osteolysis. If left unaddressed, these cysts could induce persistent pain and pose a potential risk for implant loosening,

ultimately culminating in failure. Subchondroplasty definitely serves as an effective bail-out option in such cases for effectively managing subchondral cysts of both the talus and tibial plafond.

Large lesions that measure 1.0 cm2 or greater are always at risk of articular collapse and most often than not require subchondral structural support with bone graft.(8) And in cases where the cartilage cap remains intact, procedures that require cartilage-sacrificing approach should be avoided. Retrograde drilling only offers decompression without the aforesaid bone graft support. Arthroscopically some lesions are difficult to approach and warrant open surgery with a medial or lateral malleolar osteotomy. Open surgical technique, however, is not without its inherent complications such as infection, delayed or non-union of osteotomy site, wound healing complications, risk of neurovascular injury and implant-related complications.(12) By using arthroscopy together with the minimally invasive subchondroplasty technique, we avoided all the potential complications mentioned above. Furthermore, patients reported little to no pain post-operatively and returned home on the same day of the procedure.

The findings of this study revealed significant improvements in clinical outcomes following subchondroplasty of the talus and tibial plafond. All our patients had favourable MOXFQ scores post operatively. These numbers align with previous research in larger weight-bearing joints, suggesting that subchondroplasty may be equally effective in alleviating pain and improving function in the ankle. The pain relief experienced by patients was attributed to the restoration of subchondral bone integrity and the alleviation of bone marrow edema, contributing to a more favorable joint environment.

The mean size of the cystic lesions and the AccuFill BSM were also comparable to previous studies. Whilst most authors' preference is to use bidimensional measures expressed as ellipsoid areas, we decided to use a more accurate tridimensional measures, expressed as ellipsoid volumes (cm3). In a study using both CT and Magnetic Resonance Imaging (MRI) for estimation of size of the lesions, Mc Williams et al reported a mean of 4. 73 cm3 (range 0.3-25.0), including the bone marrow edema area. Our case series, on the other hand, only used CT scans for the cystic lesion volume measurement. The post operative fill of CaP was mostly mentioned in literature as area or volume of radiodense injectate.(13,14) In addition to volume, we also quantified the percentage of the fill where all our patients had a good AccuFIll BSM of more than 50%.

The success of subchondroplasty is closely linked to appropriate patient selection and preoperative assessment. Careful evaluation of patients' medical history, imaging studies and clinical presentations is essential to identify suitable candidates for the procedure. Advanced imaging modalities, such as MRI and CT scans, play a vital role in accurately assessing the extent and nature of the cartilage and subchondral

bone defects, guiding surgical planning.(25) The triangulation method used intraoperatively very much dependent on the assessment of the pre operative imaging to identify the exact location of the lesion.

Despite the encouraging results, it is essential to acknowledge the limitations and potential complications associated with subchondroplasty. As with any surgical procedure, there is an inherent risk of infection, hematoma formation and adverse reactions to the bone substitute material. Although not encountered in our case series, previous papers have mentioned the incidence of avascular necrosis of talus post subchondroplasty. (11)

As subchondroplasty in the ankle continues to gain traction, future research endeavors should focus on multi-center, randomized controlled trials with larger sample sizes and longer follow-up periods. Additionally, investigating the potential use of regenerative materials and growth factors in conjunction with subchondroplasty may hold promise in further enhancing cartilage repair and regeneration.

While our study focused on subchondroplasty as a stand-alone treatment, comparative analyses with other treatment modalities, such as arthroscopic debridement, bone marrow stimulation or autologous chondrocyte implantation, could provide a deeper understanding of subchondroplasty's unique benefits. Such analyses will help establish its position within the broader spectrum of ankle treatment options and assist in tailoring treatment strategies to specific patient populations.

Figure 1: (From left to right) Pre subchondroplasty CT films of Patient 2 showing the talar cyst post TAR, intra-operative flouroscopy image and post operative CT films showing good fill.

Figure 2 : (From left to right) CT films of Patient 3 with tibial plafond cyst post TAR, followed by post subchondroplasty radiograph during latest follow up.

Figure 3 : (From left to right) Intra-operative flouroscopy of Patient 3, the first two images show drilling of the lesion and followed by (two images) AccuFill BSM injection.

Figure 4: (From left to right) MRI images of Patient 4 (both T1 and T2 sequences) showing the subchondral cyst in talus.

Figure 5: (From left to right) Post subchondroplasty radiograph of Patient 4 and after the subsequent definitive TAR

Figure 6 : (From left to right) Pre subchondroplasty CT of Patient 5 showing the large talar cyst, followed by intra-operative triangulation with arthroscope in-situ throughout the procedure

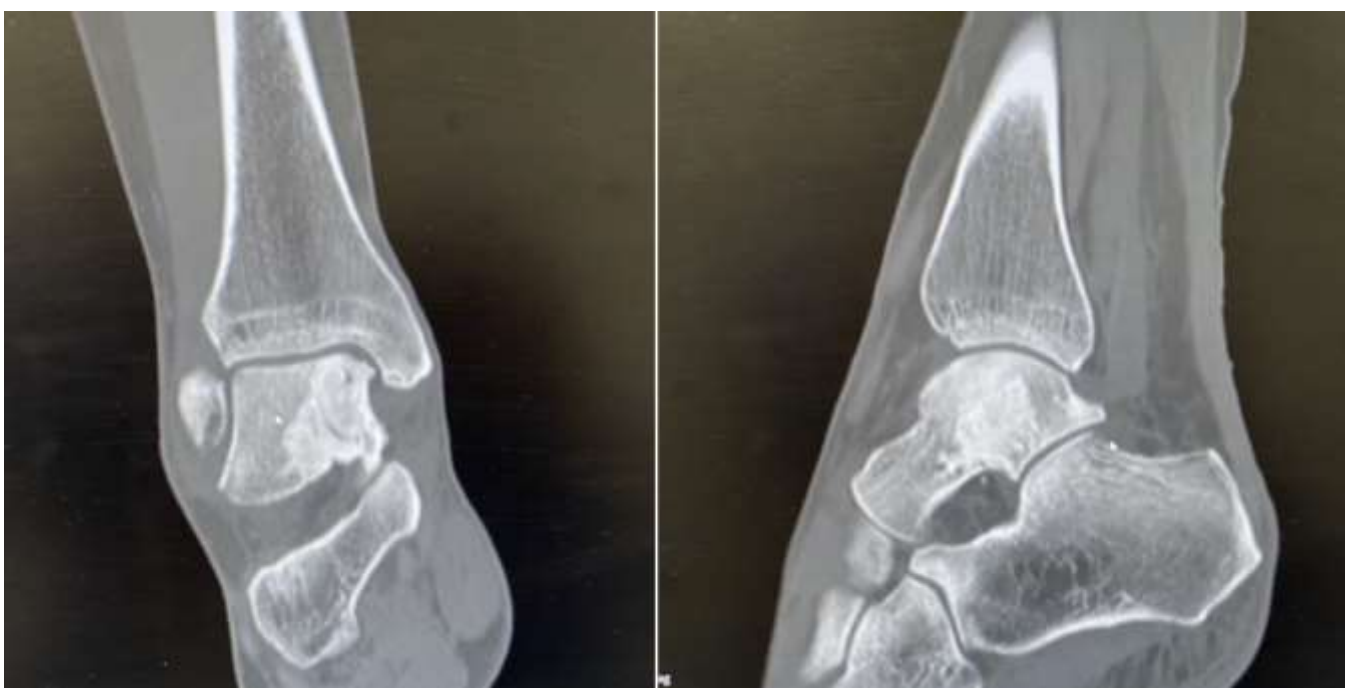

Figure 7: Post operative CT films of Patient 5 during the latest follow up.

Conclusion

Subchondroplasty demonstrates promising potential as a viable treatment option for addressing ankle-related subchondral bone defects, offering pain relief and improved joint function. It is definitely an alternative to more invasive surgical interventions, may reduce patient morbidity and shorten recovery times.

However, further research is still warranted to validate the long-term effectiveness, refine patient selection criteria and identify the optimal surgical techniques and materials. As subchondroplasty evolves, its integration into the comprehensive management of ankle subchondral lesions may revolutionize the pre-existing approach, ultimately benefiting patients' quality of life and functional outcomes.

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