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Percutaneous Revision of Non-Union Arthrodesis in the Foot

A Retrospective Review & Technique Guide

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Abstract

This retrospective case review discusses non-union of the foot, and offers a percutaneous surgical technique for revision of symptomatic non-union arthrodesis in foot surgery. We will discuss the etiology of non-union, in addition to the use of open revision with autograft as the "gold standard" for surgical intervention of this post-operative complication. We will also describe our percutaneous surgical technique for revision of non-union arthrodesis in the foot utilized in our case series of five patients. We propose that this technique is optimal in the patient that has a symptomatic non-union in the foot with uncompromised internal hardware. With this procedure, bone marrow aspirate is harvested from either the tibia or calcaneus, and after percutaneously prepping the non-union arthrodesis site under fluoroscopic guidance, the graft is injected along with a "flow-able" allograft into the non-union site. This percutaneous technique allows the patient to begin protected weight-bearing immediately post-procedure, while optimizing the potential for fusion of the non-union site.

Key Words: *Non-Union, Arthrodesis, Percutaneous Revision*

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Introduction:

Non-union is a fairly common complication that needs to be addressed by many surgeons who perform any type of bone or joint surgery involving the union of two bones. A simple definition of a non-union is an arrest of normal bone healing. Prior to 1998 the US Food and Drug Administration (FDA) defined a nonunion as a fractured bone that has not completely healed within 9 months of injury and that has not shown progression towards healing over three consecutive months on serial radiographs.

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After 1998 the FDA's Orthopedics and Rehabilitation Device Advisory Panel revised the definition of a nonunion to be a fracture that shows no visibly progressive signs of healing.[16, 17] Due to the difficult nature in addressing this problem, there are various treatment options that have been employed to treat surgical arthrodesis non-union. The most common surgical revision has been open debridement of the arthrodesis non-union with autologous bone graft. Percutaneous management with allograft is an alternative treatment method that has shown promising results for the management of fracture non-union; however more research is necessary to demonstrate its effectiveness in surgical arthrodesis non-union management. A review of the literature exhibits a lack of evidence demonstrating the effective use of percutaneous management with allograft and concentrated autologous bone marrow aspirate for

management of arthrodesis non-union in the foot and ankle.

Open revision with autograft is currently the gold standard of treatment for non-unions and is well documented throughout the literature as a viable option for management of an arthrodesis non-union.[1-4] Although open revision with autograft is one of the most common techniques utilized for the management of non-unions, this is not indicative that this procedure is without complications. Some major complications associated with autograft harvest may include: infection, prolonged wound drainage, donor site morbidity, hematoma formation, re-operation, sensory loss, and unsightly scars. Minor complications may also include superficial infection, temporary sensory loss, and harvest site pain[5]. In addition to the risks associated with graft harvest, the act of open surgical debridement of the non-union site adds to the risk of infection and further devascularizes the osseous structures secondary to soft tissue dissection and periosteal stripping.[6] More invasive revisional techniques open to door to surgical morbidity, increased medical cost and socioeconomic issues for the patient secondary to lost wages and inability to work. Due to the complications associated with open management of non-unions other methods have been sought after which may decrease the inherent risks associated with revision of a non-union utilizing open technique.

The powerful potential of bone marrow aspirate was first investigated in the 19th century.[7] Even though bone marrow aspirate can be employed to stimulate new bone formation, clinical applications of its use have recently made significant advances. In 1989 Connolly et al. demonstrated the effectiveness of using bone marrow aspirate with a percutaneous approach. In his research he evaluated 10 cases of delayed tibial unions. All the patients sustained high-energy fractures to the tibia that had displayed no sign of significant radiographic evidence of healing for three consecutive months. All patients were treated on an outpatient basis using percutaneous marrow injection rather than standard operative technique. Nine of the ten patients responded with radiographic evidence of bony callus formation in the area of marrow injection. In 1998, Connolly[8] reviewed his various methods and techniques of using marrow osteoprogenitor cells spanning a 15-year time period. He found that marrow injection can be useful in treating numerous skeletal healing problems, including delayed unions or nonunion, when the marrow was injected in and about a nonunion site. In 2013 Kassem[10] accessed 20 patients who had non-unions of fractures sustained to tibia, femur or ulna. All patients were managed with percutaneous harvest of bone marrow and injection of the aspirate into and around the non-union site. Nineteen out of twenty fractures went on to clinical and radiological unions.

While there is significant evidence to support the effectiveness of percutaneous management of fracture non-unions, there is a paucity of literature demonstrating its effectiveness in surgical arthrodesis non-union. There is even less evidence in the literature detailing the use of percutaneous bone marrow harvest in conjunction with percutaneous non-union site preparation with allograft application for the treatment arthrodesis non-union. It is the authors' belief that the use of percutaneous concentrated bone marrow aspirate in the setting of percutaneous non-union site preparation with allograft application is a potential option for the treatment of arthrodesis non-union in the foot.

Materials and Methods

Patient Selection

After institutional review board approval, the surgical logs of a single foot and ankle surgeon were reviewed to identify patients that had surgical percutaneous allograft with concentrated autologous bone marrow aspirate for symptomatic non-unions after arthrodesis surgery from April 2012 through June 2015**.** The diagnosis of a non-union was made in patients that demonstrated no signs of bony trabeculation, or progression towards such, across the arthrodesis site after a minimum of three months of serial imaging. Only patients with symptomatic non-unions of the midfoot or forefoot with intact and stable fixation across the arthrodesis site were selected for the procedure. (Figure 1) Unstable, broken, or perifixation lucencies were contraindications for this procedure. The clinical records were obtained and reviewed for 5 patients that met the criteria for this technique. We abstracted demographic information, including age, gender, and patient comorbidities. Initial arthrodesis surgery, non-union revision date, date of bony trabeculation and date of complete union were also assessed. Patients were followed

postoperatively by the operating surgeon. All patients were clinically evaluated and underwent serial plain film radiographs on each clinical visit to record the healing progress of the arthrodesis sites. Patients who were classified as having complete union of the arthrodesis site were confirmed radiographically and demonstrated resolution of pre-operative symptoms at the non-union site.

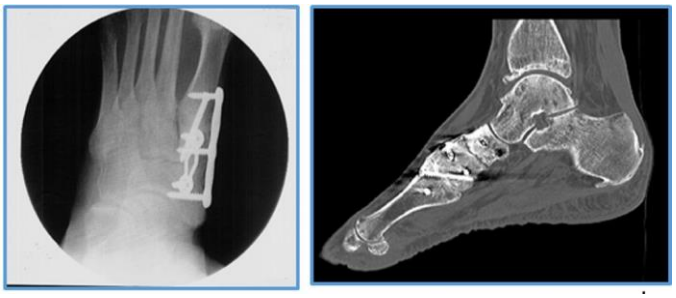

Figure 1*: (A) Radiograph demonstrating intact hardware with the presence of a non-union of the naviculocuneiform join; (B) CT scan confirming non-union of the naviculocuneiform joint*

Surgical Technique

The patient is placed in a supine position on the operating table and, depending on the arthrodesis revision site, the foot may or may not be bumped to provide better access to the area of revision. Attention is directed to the lateral aspect of the calcaneus for purposes of harvesting bone marrow aspirate. A stab incision is made in a safe zone on the lateral calcaneal wall inferior the peroneal tendons and sural nerve. Through this same incision a Jamshidi needle is then introduced into the calcaneal body and bone marrow aspirate (BMA) is then harvested (Figure 2).

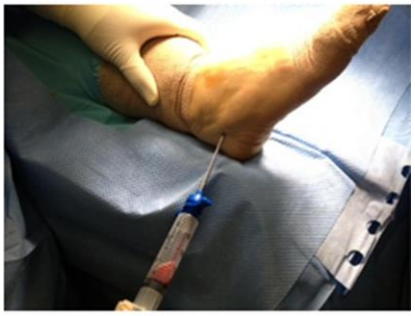

FIGURE 2*: Insertion of the Jamshidi into the lateral calcaneus for the harvest of BMA*

It should be noted that the Jamshidi needle should be redirected at the harvest site for every 10-15mL of BMA collected. Approximately 60 mL of bone marrow is typically harvested to provide sufficient marrow for concentration. (Note: If the calcaneus is not an optimal site for harvesting, the surgeon may harvest from the anterior proximal tibia, just medial to the tibial tuberosity or the distal tibial metaphysis). After the bone marrow is harvested it is then passed from the operative field and concentrated. In all procedures, the BMA was concentrated to 4 mL using the Arteriocyte Magellan® system. The concentrated BMA is then mixed with injectable or flowable allograft. In all cases, Wright Medical IGNITE® Power Mix allograft was utilized. The IGNITE® Power Mix combines an injectable cellular scaffold in demineralized bone matrix with autologous concentrated bone marrow aspirate. The combination provides a minimally invasive graft with osteoconductive, osteoinductive, and osteogenic capacity.

A small percutaneous incision is made over the non-union arthrodesis site confirmed via fluoroscopy. Through this small incision pointed trocar, wire pass drill bit, rasp, and / or small curette are used to debride the non-union site of any fibrocartilage (Figure 3).

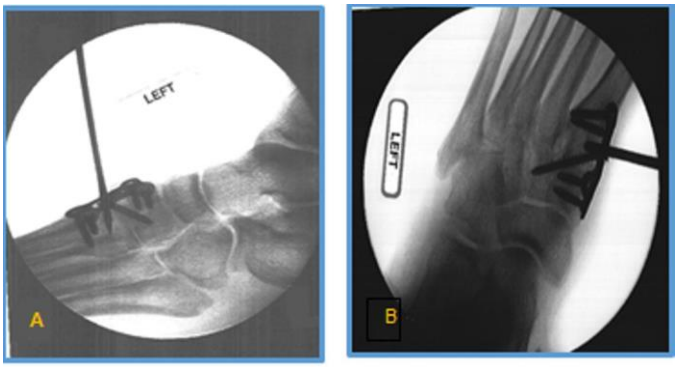

FIGURE 3*: (A) Lateral view. Pointed trocar being introduced into a TMTJ non-union site percutaneously as intraoperative fluoroscopy is used to confirm proper location of instrumentation. (B) AP view of trocar, again ensuring proper location of instrumentation.*

It should be noted that any hardware in place is undisturbed. The cortical rim around the arthrodesis non-union is not debrided to allow direct bone-to-bone contact to prevent loss of hardware stability. After the non-union site is sufficiently debrided, a K-wire or wire pass drill is then used to perforate the subchondral plate on the proximal and distal sides of the arthrodesis site. Once the joint has been properly prepared, the mixture of cBMA and allograft is injected into the debrided nonunion site. This only requires one to two ml of allograft / cBMA mixture and care should be taken to avoid inadvertent injection of the graft into the surrounding soft tissues.

Intraoperative fluoroscopy is utilized to confirm accurate injection of the substrate (Figure 4).

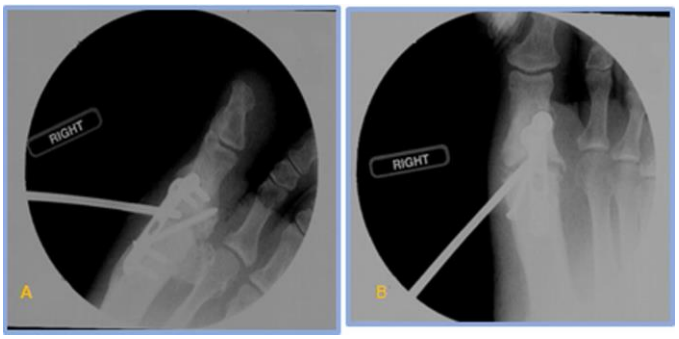

***Figure 4**: Injection of cBMA and wright medical ignite substrate into the prepared non-union site of the 1st metatarsophalangeal joint, intraoperative fluoroscopy is used to confirm proper location*

Once the graft has been placed into the non-union site, the skin is then closed with 4-0 Monocryl suture. A dry, sterile dressing is then placed on the operative site/foot.

Procedural time is notably less than full take down revision and grafting of the surgical non-union site. The procedure is performed on an outpatient basis. Analgesic utilization postoperatively was noted to be dramatically less secondary to the minimally invasive approach to this procedure. Due to the fact that this procedure is reserved for patients where there is no compromise of the hardware or fixation at the arthrodesis site, the patients are returned to the ambulation status, which they had preoperatively. All patients were permitted full weight-bearing on the surgical foot immediately postoperatively in a short cast boot, surgical shoe, or forefoot wedge shoe. This enabled quicker return to work and an improved quality of life in the immediate post-operative period.

Results

Three of the five patients observed in the study were demonstrated to have complete radiographic or CT confirmed union of the non-union site. The average time from non-union revision date to complete union in the group of three that healed was 17 weeks. Four of the patients experienced resolution of pain associated with the non-union with return to normal activities and improved quality of life. One patient who had not achieved complete union across the arthrodesis site had continued symptoms and elected for a traditional open revision. No complications were observed in any of the patients. (Tables 1 &2; Figure 5)

***Table 1:** Patient Data (Non-union site vs. co-morbidities)*

	Arthrodesis site	Co-morbidities
Patient #1	1st MTPJ arthrodesis	Hypercholesterolemia, Esophageal reflux, Hypertension, Stress, Anxiety, Vitamin D deficiency, DJD
Patient #2	Navicular-cuneiform arthrodesis	Hypercholesterolemia, Esophageal reflux, Hypertension, Hypothyroidism, Depression, Vitamin D deficiency, tobacco use
Patient #3	Navicular-cuneiform arthrodesis	Esophageal reflux, Hypertension, Arthritis, Vitamin D deficiency
Patient #4	1st TMTJ arthrodesis	Tachycardia, Vitamin D deficiency
Patient #5	1st and 2nd TMTJ arthrodesis	Vitamin D deficiency

***Table 2**: Patient time to healing (in weeks)*

Patient	Arthrodesis Site	Revisional Surgery Date	Time to Boney Trabeculation (weeks)	Time to Complete Healing Across Site (weeks)
1	1st MTP	8/13/2014	12	No complete radiographic union
2	Navicular Cunieform Joint	5/7/2014	9	No complete radiographic union
3	Navicular Cunieform Joint	1/8/2014	4	21
4	1st Tarsometatarsal Joint	6/7/2013	8	25
5	1st and 2nd Tarsometatarsal Joint	7/24/2013	2	10

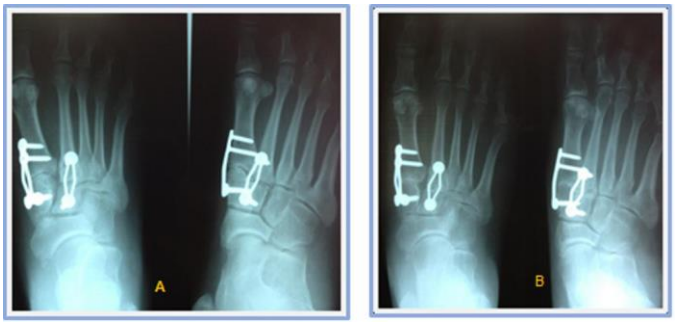

***Figure 5**: (A) Pre-op x-rays of a non-union of the 1st TMTJ. (B) X-rays after percutaneous non-union revision.*

Discussion

Surgical non-unions are a very challenging problem that any surgeon who performs arthrodesis must be capable of managing. The gold standard for surgical treatment of arthrodesis non-unions has been open revision with grafting. Surgical arthrodesis revision surgery presents a host of ill effects on the patient's that require this treatment. Surgical morbidity, decreased quality of life, inability to work with lost wages and escalating medical costs compound the physical and mental anguish revisional surgery may create.

In an attempt to minimize the surgical burden created with more traditional methods of non-union management, research has been focused on less invasive techniques such as low-intensity ultrasound, extracorporeal shock waves, bone growth factors, and bone marrow injection.[11, 12, 13]

When first line treatments of non-union management fail, percutaneous management of non-unions offers an excellent alternative to open revision in cases where the hardware of the non-union site is intact and not compromised. It is also essential that non-union sites are uninfected. In the five case we have presented, all patients had been diagnosed with a non-union by the following: a non-healed arthrodesis site for 9 months or longer, no radiographic signs of healing for the past 3 months or longer, and pain at the non-union site. All patients were shown to have intact and stable hardware at the arthrodesis site, which is essential for the success of a percutaneous revisional technique.

It is important to also note that all 5 patients in our study were found to be deficient in vitamin D and were subsequently started on oral vitamin D supplementation. Even though 100 percent of our nonunion patients were found to be vitamin D deficient, this does not prove a causal link between vitamin D deficiency and a non-union. Regardless, it is the author's opinion that metabolic optimization is another factor that should be addressed when managing patients with a non-union.

In our technique, the bone marrow obtained was concentrated by the use of centrifuge. In 2005, Hernigou et al.[14] recommended the use of concentrated bone marrow through the use of centrifuge in order to increase the number of osteoprogenitor cells in the bone marrow injected. With this technique, 4 ml of cBMA is an ample amount for the percutaneous technique. (Figures 6 & 7)

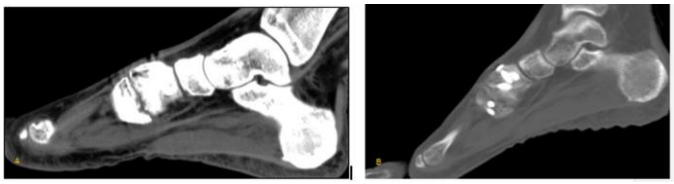

***Figure 6**:(A) CT confirmed non-union of 1st TMTJ arthrodesis. (B) CT confirmed central boney bridging across previously noted non-union 2 months after percutaneous BMA grafting.*

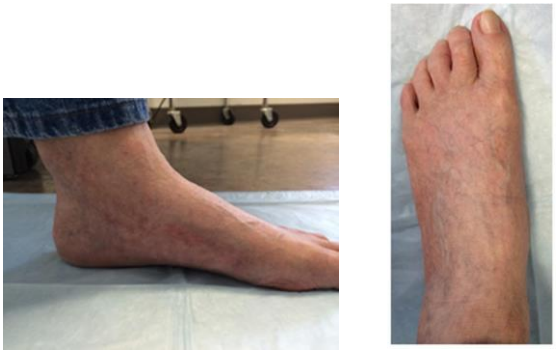

***Figure 7**:Post-operative photos after navicular cuneiform joint non-union percutaneous revision.*

Conclusion

With 80% of patients experiencing symptom relief and only 60% achieving bony consolidation at the arthrodesis site after percutaneous revision and all patient's we feel these outcomes merit further application and investigation of this technique in the appropriate patient population with extensive informed consent. This technique, if proven to provide acceptable rates of arthrodesis and symptom resolution, may dramatically reduce the co-morbidities, cost, and burden or open surgical non-union revisions.

Acknowledgments

None

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