

MICROFRACTURE IN THE TREATMENT OF KNEE CHONDRA L INJURIES

– Written by Karen K. Briggs, Lauren M. Matheny and Steven B. Singleton, USA

The treatment of chondral lesions of the knee remains, even today, a dilemma for the orthopaedic surgeon or sports medicine physician. Symptoms and levels of impairment from articular cartilage lesions of the knee vary greatly between individuals. For those lesions that cause symptoms in patients, several lines of treatment have been developed. Of these treatment strategies, the most common and most useful is microfracture – an arthroscopic procedure and rehabilitation programme that was developed in the early 1980s by Dr J. Richard Steadman. Today, microfracture is still the most commonly utilised articular cartilage repair procedure throughout the world. This manuscript will detail the origins of microfracture, the proper way to perform the procedure and subsequent rehabilitation and the published results of this treatment.

The original description and regimen for microfracture was a combination of surgery and rehabilitation which would allow cartilage repair tissue to form in the articular cartilage defect. The surgical goal was to create fractures in the subchondral bone perpendicular to the surface. Through these fractures, blood and marrow elements would be released and form a ‘super’ clot. To reach all areas of the knee joint, various angled picks were developed. Previous work had been done with drills, but drills could not reach all areas of the joint and produced heat when used, which could limit the development of new tissue

Several peer-reviewed basic science studies proved the concepts behind microfracture in the 1990s and 2000s¹⁻⁴. The first study evaluated the percentage of fill and the collagen content in the repair tissue¹. At 4 and 12 months following microfracture,

there was more repair tissue in defects that were treated with microfracture compared to untreated lesions. In addition, type II collagen was increased, with 74% type II collagen at 12 months. Earlier bone remodelling was noted by changes in porosity¹. The next basic science study proved that the removal of the calcified cartilage layer improved the grade of the repair tissue and the filling of the lesion².

To further understand the composition of the repair tissue, Frisbie et al³ looked at key matrix component expression in early cartilage healing following microfracture. Samples were collected at 2, 4, 6 and 8 weeks. The study showed that over the 8 week period, mRNA levels for type II collagen, as well as aggrecan, gradually increased in the microfracture group. These findings supported non-weightbearing for 8 weeks in patients with microfracture on

weightbearing surfaces. The basic science study showed that the repair cartilage was not adequately mature until 8 weeks³.

One of the first studies on outcomes compared patients who used continuous passive motion (CPM) following microfracture⁵. Based on second-look arthroscopies, the study concluded that patients who used CPM had improved cartilage healing. This study supported the use of CPM for 8 weeks following microfracture, in addition to non-weightbearing⁵.

INDICATIONS

Several factors to take into consideration for use of the microfracture procedure include patient age, acceptable bio-mechanical alignment of the knee, activity level, the patient's willingness to accept the extensive rehabilitation protocol and the individual's expectations. If all of these criteria are met, then microfracture may be a suitable treatment option for the patient.

In addition, it is extremely important to manage the patient's expectations. Patient-centered questionnaires are important to understand the patient's symptoms and limitations in function. In Vail, we utilise an outcomes-based approach to foster improvements in patient care and our patient-centred research has helped us to identify the most important factors in the success of microfracture surgery.

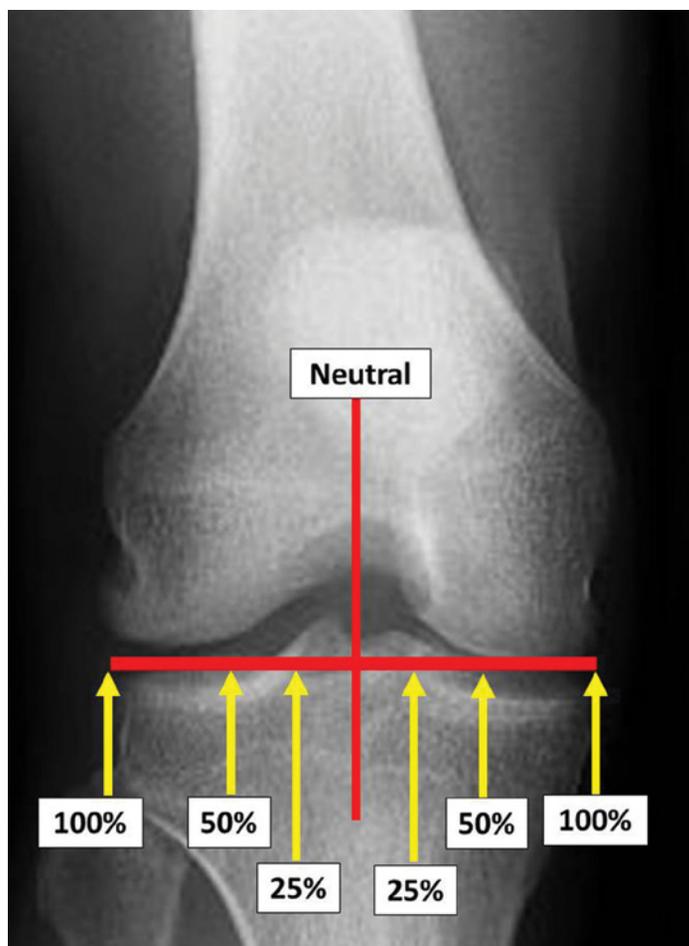


Figure 1: When assessing alignment, the line between the hip and knee crosses through the knee joint. If the line lands outside of the 25% line, microfracture on the weightbearing condyles maybe contraindicated.

Imaging is also necessary for proper patient selection. To determine angular deformity, a long-standing hip to ankle image radiograph is taken. Axial alignment is measured by drawing a line from the center of the head of the femur to the centre of the tibiotarsal joint and assessing the load-bearing line within the knee joint⁶. With the centre of the joint being 0% or neutral alignment and 100% being the outside edge of the condyles, alignment outside of 25% on the medial or lateral side may result in inferior results following microfracture (Figure 1). The patellofemoral joint is also evaluated by way of radiographic patellar views. Standard anteriorposterior and lateral images are also reviewed. Images with both knees flexed to 30 or 45 degrees in a weightbearing position are also included. In the case of a suspected chondral defect, a magnetic resonance image (MRI) allows for confirmation of the articular cartilage defect and allows for analysis of co-pathologies.

SURGICAL TECHNIQUE

A thorough diagnostic arthroscopic examination of the knee is performed. Although a tourniquet is not generally used during the microfracture procedure, the arthroscopic fluid pump pressure is varied to control bleeding. Microfracture is the final intrarticular procedure performed. Performing the microfracture last prevents loss of visualisation when blood and fat droplets enter the knee joint and reduces the chance of the marrow clot being dislodged.

The basic steps to perform the microfracture procedure are listed in Table 1. Preparation of the cartilage lesion (Figure 2) creates a stable perpendicular edge of healthy, well-attached, viable cartilage surrounding the defect, serving as a pool that helps contain the marrow clot ('super clot'). If the surrounding cartilage is too thin, the marrow elements and blood will not be contained and a clot will not form.

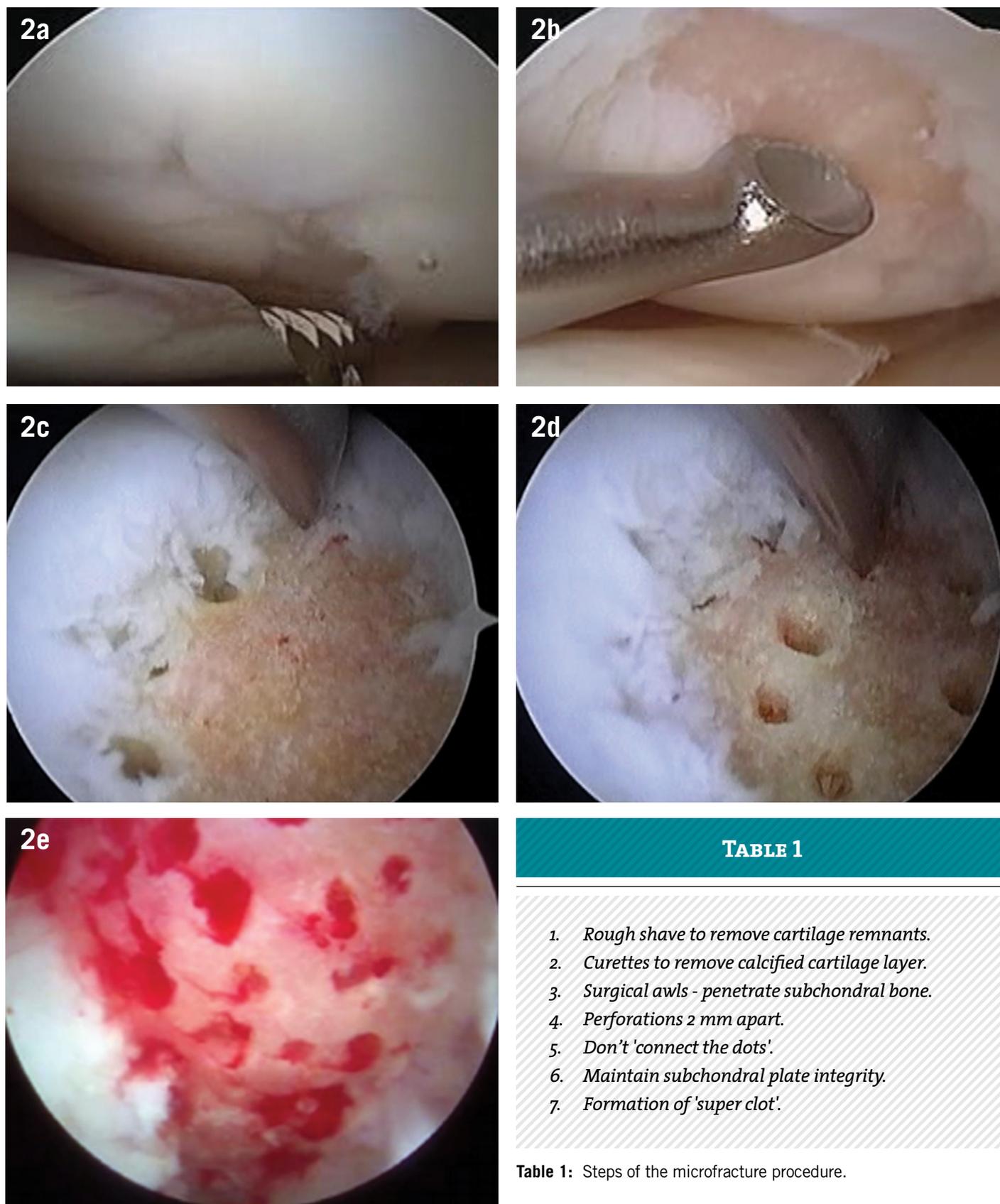


TABLE 1

1. *Rough shave to remove cartilage remnants.*
2. *Curette to remove calcified cartilage layer.*
3. *Surgical awls - penetrate subchondral bone.*
4. *Perforations 2 mm apart.*
5. *Don't 'connect the dots'.*
6. *Maintain subchondral plate integrity.*
7. *Formation of 'super clot'.*

Table 1: Steps of the microfracture procedure.

Figure 2: Microfracture technique. a) Unstable and cartilage remnants are removed. b) Curette is used to remove calcified cartilage layer. c) Microfracture performed with surgical awls. d) Microfractures fill the defect without connecting. e) A completed microfracture with blood and marrow elements coming from microfracture holes.

Microfractures are made in the articular cartilage lesion with the awls. The awl should be perpendicular to the bone as it is advanced. A 90° awl is used for the patella if an angle cannot be created to accommodate the 45° awl. It is important that the 90° awl only be advanced manually, with no use of a mallet. Microfracture holes are made around the edge of the defect and then continued to the center (Figure 3). When all of the holes have been made, the fluid pressure is reduced to verify the release of fat droplets and blood from the microfracture holes. Microfracture creates a rough surface on the subchondral bone (Figure 4). This surface allows the marrow clot to adhere more easily, while the integrity of the subchondral plate is maintained for joint surface shape.

For successful outcomes, the joint environment must be corrected if indicated. It is critical that there is adequate space in the knee and no limitations in full motion. Arthrofibrosis, infrapatellar or suprapatellar plica and anterior interval scarring can all limit the joint space⁷. In most cases, these can be corrected at the same time as the microfracture procedure.

POST-OPERATIVE PROTOCOL

When developing the microfracture procedure, Dr Steadman recognised that development of a post-operative protocol was needed to protect the repair and

facilitate cartilage regrowth. Most prior cartilage procedures had little to no emphasis on the post-operative period. The goal of the protocol was to create an environment which allows maximum differentiation of repair tissue. The size and location of the treated lesion determines specifics of the rehabilitation plan. The particular protocol of the rehabilitation programme should be tailored to the procedures that have been performed on the patient to ensure the best possible outcomes.

When microfracture is performed on the weightbearing surfaces of the femoral condyles or tibial plateaus, mobilisation begins immediately after surgery, with a CPM machine in the recovery room. Initially, range of motion is roughly 30 to 70 degrees and the machine will cycle once per minute. This will be increased as tolerated by the patient. The goal is to have the patient on the machine for 6 to 8 hours in a 24 hour period. The ultimate goal here is for the patient to gain complete passive range of motion as soon as possible post-surgery. In addition, there is an emphasis on range of motion of the patella and patellar tendon motion. Patellar mobilisation exercises are taught to the patient on the first day following surgery. All patients receive cold therapy after surgery to reduce inflammation as well as pain. Cold therapy is usually implemented for 1 to 7 days after surgery.

Crutch-assisted touch-down weight-bearing ambulation is prescribed for up to 8 weeks based on the size of the lesion. In patients with smaller lesions, less than 1 cm, this prescription may be shorter. For this, patients will place about 10% to 30% of their body weight on the injured leg. Between 1 and 2 weeks after surgery the patient will be placed on a stationary bike without resistance and begin a deep-water exercise programme that involves running. Flotation will be used so that the injured leg does not touch the bottom of the pool. This is an imperative step and must be followed.

At roughly 8 weeks the patient progresses to full weightbearing. On occasion, an unloader brace prescribed for the appropriate compartment, is used as weightbearing is progressed to normal to protect the healing lesion. Then, a period of dynamic biking with increasing resistance. Biking is the fundamental exercise to rebuild strength between 8 and 16 weeks post-surgery. Elastic resistance band programmes are added at 12 weeks following the detailed description that has been published⁸.

All patients treated by microfracture for patellofemoral lesions will be put in a brace with motion limited to 0° to 20° for at least 8 weeks. This range of motion limits compression of the regenerating surfaces of the trochlea or patella or both. Passive



Figure 3: When starting microfracture, holes are made close to the edge of the defect.

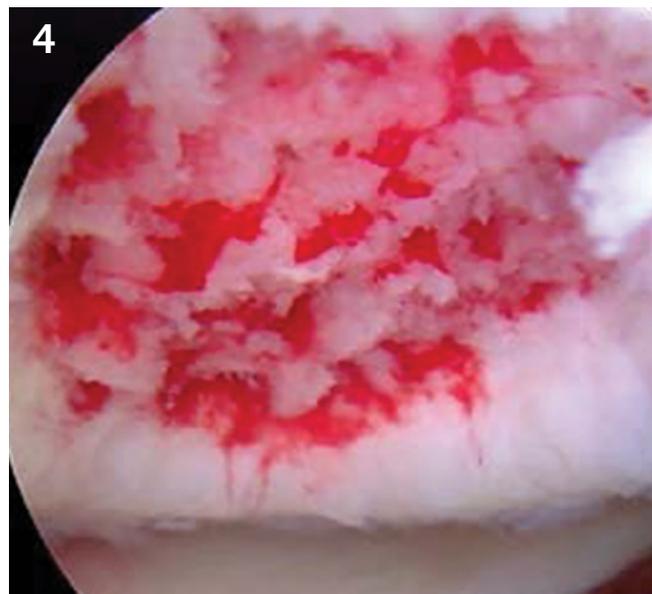


Figure 4: Microfracture creates a rough surface which helps hold the clot in place.

Developed in the early 1980s by Dr J. Richard Steadman, today microfracture is still the most commonly utilised articular cartilage repair procedure throughout the world

motion is allowed with the brace removed, but otherwise the brace must be worn at all times. The brace is removed for CPM usage and replaced following CPM usage. For patients with patellofemoral joint lesions, joint angles are carefully observed at the time of arthroscopy to determine where the defect comes into contact with the patellar facet or the trochlear groove. These angles are avoided during strength training for approximately 4 months. This avoidance allows for immediate training in the 0° to 20° range postoperatively because there is minimal compression of these chondral surfaces with such limited motion.

Patients with lesions of the patellofemoral joint treated with microfracture are allowed weightbearing as tolerated in their brace 2 weeks after surgery. After 8 weeks, the brace is gradually opened and then discontinued. When the brace is discontinued, patients are allowed to advance their training progressively. Starting 12 weeks after microfracture, the exercise programme is the same one used for femorotibial lesions.

Improvement in knee function may not occur for at least 6 months after microfracture, so patients are counselled preoperatively so they understand what to expect after surgery. Improvement has been shown to occur slowly and steadily for at least 2 years, which has been supported by our clinical research data⁹. The repair tissue matures, pain and swelling resolve

and patients regain confidence and comfort in their knees during increased levels of activity during this time period.

OUTCOMES FOLLOWING MICROFRACTURE

The first long-term outcomes paper was published on the microfracture technique in 2003⁹. This study followed 72 patients with acute chondral lesions at an average of 11 years after microfracture, with the longest follow-up being 17 years. The results showed a decrease in symptoms and improved function. The study identified age as the only independent predictor of Lysholm improvement. Patients over 35 years of age improved less than patients under 35 ($p=0.048$); nonetheless both groups showed improvement⁹.

Recently, a study compared the outcomes of autologous chondrocyte implantation with microfracture treatment in a randomised trial¹⁰. Forty patients were treated in each group. At 2 years, both groups showed significant improvement on the Lysholm scale and, particularly, pain, with no difference between the groups. However, the microfracture group had more improvement in the Short Form-36 physical component score¹⁰. A follow-up to this study showed no differences at 5 years¹¹.

Cartilage injuries are common in high-impact sports. In American football, 25 active National Football League players were treated with microfracture between 1986 and 1997. By the next season, 76% of

the players returned to play and continued to play for an additional 4 seasons. All players showed decreased symptoms and improvement in function. Of those players who did not return to play, most had pre-existing degenerative changes of the knee¹². In a group of professional skiers who underwent microfracture, excellent patient-centered outcomes were seen at an average of 77 months follow-up¹³. The median postoperative Tegner activity scale was 10 (range 4 to 10), even 7 years after professional skiing. One patient did not return to skiing. The average time from surgery to return to competition was 13.4 months (range 0.5 to 25.3 months). Among skiers with a World Cup ranking, improved ranking was seen in the majority. The study showed that microfracture, with the recommended post-operative protocol, is an acceptable treatment option for elite skiers who have full thickness articular cartilage lesions of the knee. Microfracture has also been successful in young patients¹³. In patients between 12 and 18 years old, excellent outcomes and high patient satisfaction was found at an average of 5.8 years following microfracture¹⁴. Only one patient required a revision microfracture of a trochlear defect. These young patients returned to full activity with no disability from their knee injury. Many other studies have documented varied results following microfracture. Most of these studies did not follow the post-operative protocol.

For optimal results it is critical to follow the surgical technique and post-operative protocol as originally described.

CONCLUSION

Now 30 years since it was developed, microfracture is performed in the knee, hip, shoulder, elbow, ankle and hand joints. When done correctly with the correct post-operative protocol, microfracture has been shown to be very successful in returning patients to their desired activities. Today microfracture has its own surgical billing procedure code (CPT) and over 300 publications are referenced in Pubmed on microfracture in the knee. In 2012, the paper 'Outcomes of microfracture for traumatic chondral defects of the knee: average 11-year follow-up' by Dr Steadman and others was named one of the top 25 most cited articles in all of the arthroscopic orthopaedic literature and in 2014 it was named as one of the top 100 papers in knee orthopaedic literature. Today, microfracture is the most common cartilage repair technique being used in the USA and its incidence continues to grow.

In conclusion, microfracture is a safe and effective method to treat cartilage defects of the knee. Many factors may play a role, including patient compliance with rehabilitation, the size, depth and location of the lesion and the overall condition of the joint surfaces in the outcome following microfracture.

References

1. Frisbie DD, Trotter GW, Powers BE, Rodkey WG, Steadman JR, Howard RD et al. Arthroscopic subchondral bone plate microfracture technique augments healing of large osteochondral defects in the radial carpal bone and medial femoral condyle of horses. *J Vet Surg* 1999; 28:242-255.
2. Frisbie DD, Morrisset S, Ho CP, Rodkey WG, Steadman JR, McIlwraith CW. Effects of calcified cartilage on healing of chondral defects treated with microfracture in horses. *Am J Sports Med* 2006; 34:24-31.
3. Frisbie DD, Oxford JT, Southwood L, Trotter GW, Rodkey WG, Steadman JR et al. Early events in cartilage repair after subchondral bone microfracture. *Clin Orthop* 2003; 407:215-227.
4. Steadman JR, Rodkey WG, Briggs KK. Microfracture: its history and experience of the developing surgeon. *Cartilage* 2010; 1:78-86.
5. Rodrigo JJ, Steadman JR, Silliman JF, Fulstone HA. Improvement of full-thickness chondral defect healing in the human knee after debridement and microfracture using continuous passive motion. *Am J Knee Surg* 1994; 7:109-116.
6. Steadman JR. The microfracture technique. In: *The crucial principles in care of the knee*. Philadelphia: Lippincott Williams & Wilkins 2007.
7. Steadman JR, Dragoo J, Hines S, Briggs KK. Arthroscopic release for symptomatic scarring of the anterior interval of the knee. *Am J Sports Med* 2008; 36:1763-1769.
8. Hurst JM, Steadman JR, O'Brien L, Rodkey WG, Briggs KK. Rehabilitation following microfracture for chondral injury in the knee. *Clin Sports Med* 2010; 29:257-265.
9. Steadman JR, Briggs KK, Rodrigo JJ, Kocher MS, Gill TJ, Rodkey WG. Outcomes of microfracture for traumatic chondral defects of the knee: average 11-year follow-up. *Arthroscopy* 2003; 19:477-484.
10. Knutsen G, Engebretsen L, Ludvigsen TC, Drogset JO, Grøntvedt T, Solheim E. Autologous chondrocyte implantation compared with microfracture in the knee. A randomized trial. *J Bone Joint Surg Am* 2004; 86:455-464.
11. Knutsen G, Drogset JO, Engebretsen L, Grøntvedt T, Isaksen V, Ludvigsen TC, et al. A randomised trial comparing autologous chondrocyte implantation with microfracture. Findings at five years. *J Bone Joint Surg Am* 2007; 89:2105-2112.
12. Steadman JR, Miller BS, Karas SG, Schlegel TF, Briggs KK, Hawkins RJ. The microfracture technique in the treatment of full-thickness chondral lesions of the knee in National Football League players. *J Knee Surg* 2003; 16:83-86.
13. Steadman JR, Hanson CM, Briggs KK, Matheny LM, James EW, Guillet A. Outcomes after knee microfracture of chondral defects in alpine ski racers. *J Knee Surg* 2014; 27:407-410.
14. Steadman JR, Briggs KK, Matheny LM, Guillet A, Hanson CM, Willimon SC. Outcomes following microfracture of full-thickness articular cartilage lesions of the knee in adolescent patients. *J Knee Surg* 2015; 28:145-150.

Karen K. Briggs M.P.H
Director, Center for Outcomes-based
Orthopaedic Research
Steadman Philippon Research Institute

Lauren M. Matheny B.A.
Co-ordinator of Lower Extremity Research
Steadman Philippon Research Institute

Steven B. Singleton M.D.
Orthopaedic Surgeon
The Steadman Clinic

Researcher
Steadman Philippon Research Institute
Vail, Colorado, USA
Contact:
ssingleton@thesteadmanclinic.com