A Comparative Study of Microfracture and Drilling Surgical Techniques for Cartilage Repair

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Introduction: Bone marrow stimulation initiates cartilage repair by inducing a fracture repair response in subchondral bone [1]. Clinical treatment algorithms recommend microfracture (MF) where a surgical awl is used to pierce subchondral bone, although drilling and abrasion are also practiced [2-3]. No study has compared the effectiveness of these techniques. The current study compares MF to microdrilling (MD) in a rabbit model and also examines the effect of hole depth on repair responses.

Materials and Methods: Trochlear and condylar cartilage defects were prepared bilaterally in adult NZW rabbits (8-9 months old, n=26). On each defect, cylindrical holes 2mm or 6mm deep were made with a 0.9 mm dia drill bit, while a mini-microfracture awl pierced conically shaped holes 2mm deep. Animals were sacrificed at 1, 14, 21 and 90 days post-operation. Fixed joints were scanned by microCT followed by histology using non-decalcified MMA, and decalcified cryo and paraffin embedding. Sections were stained with Goldner's Trichrome, Safranin-O/Fast Green, Gomori's trichrome, and with antibodies including anti-collagen type I, II and X, and anti Ki-67, a marker of cell proliferation. Pre-operative osteochondral characteristics were assessed using non-operated controls.

Results: We found compacted and fractured bone around MF holes at 1 day post-op while MD holes displayed clean borders free of bone debris (Figs. 1 a-c and Fig. 2a). The subchondral hematoma was extensive with both techniques and occupied a subchondral region ~5 times the volume of the holes (Fig. 1a). Notably, heat necrosis due to MD could not be identified.

At 14 days post surgery, compact fractured bone was still present at the border of MF holes (Fig. 1f). Chondrogenic foci, the source of cartilaginous tissues in marrow-derived cartilage repair procedures, were observed more frequently and more rapidly in the drilled compared to MF holes (Fig. 1c) and were also associated with higher levels of vascularization in granulation tissue. Chondrogenic foci were positive for collagen II by immunostaining (Fig. 3c). Both micro-CT scans and histology demonstrated substantial bone synthesis in the osteous zone within and below the MD holes in comparison to less bone synthesis in MF holes at the intermediate repair stages (Fig. 2c). We also found that deeper holes led to a greater extent of bone damage (Fig. 2d) and subchondral hematoma at Day 1 post-op, although new bone (Fig. 2e-f) and chondrogenic foci were apparent later.

Preliminary results at 3 months of repair showed bone remodeling to extend far beyond the hole region, and hole borders can not be identified. Cartilage defects were covered with a thin attached and relatively well integrated repair tissue (Fig. 3d). Further evaluation at 3 months is ongoing.

Discussion: Within the bone marrow stimulation family of surgical treatment on cartilage defects, MF is most popular and is thought to be an improvement on previous drilling methods. Our study revealed distinctly different consequences of MF versus MD on the subchondral bone and subsequent repair responses. MF induced acute fracturing and crushing of bone resulting in compacted bone surrounding the holes that could impede repair and access to cancellous marrow. This may be the cause of reduced new bone synthesis and fewer chondrogenic foci seen in MF versus MD holes at intermediate stages of repair.

The deeper bone marrow was more cellular than shallower bone marrow. Thus drilling holes down to 6mm deep may recruit a different cell population than for 2mm holes. Deep holes stimulated rapid intramembranous bone formation in deeper compartments of the holes and at Day 21, substantial bone filling was already observed in 6 mm holes.

In summary, significant differences in acute subchondral bone damage and subsequent repair responses were found comparing MF to MD. These methods and hole depth may affect the patterns and connectivity of subchondral bone marrow channels to possibly influence the effectiveness of long term cartilage repair.


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Figure 1. Goldner’s Trichrome stained MMA sections from trochlea of rabbits sacrificed at 1 (a-c) and 14 (d-f) days post-op. Bone compaction around MF holes was accompanied by fracturing (c and f), which was absent with drilling (b and e). MD2 and MF2 represent MD and MF holes of 2mm deep, respectively.

Figure 2. Micro-CT scans of rabbit trochlear defects at Day 1 (a and d), Day 14 (b and e) and Day 21 (c and f) post-surgery. MD6 indicates 6 mm deep MD holes. Bone compaction appears around MF holes (blue arrows) but not around MD holes. On day 21, new bone formation is more advanced in MD holes (green arrows) than MF holes. Original pixel size is 10 microns.

Figure 3. Transverse sections of rabbit cartilage defects after 14 days (a-c) and 3 months (d) of repair. Sections were stained with Safranin O-Fast Green (a), collagen II (b-c), and Goldner’s Trichrome (d).