Depth and Type of Subchondral Perforation Influence the Outcome of Cartilage Repair using Bone Marrow Stimulation


INTRODUCTION
Subchondral drilling and microfracture are bone marrow stimulation techniques commonly used for the treatment of cartilage defects. Few studies to date have examined the technical variants which may influence the success of these surgical procedures. We have recently showed in a rabbit model that irrigated subchondral drilling produced no apparent acute bone necrosis and cleanly removed subchondral bone rather than compacting it around the periphery of the hole as we found in microfracture. In this follow-up study of 3 month repair, we tested the hypotheses that the 6 mm deep drilling generates repair tissue of a greater quantity and hyaline quality than the 2 mm shallow drilling and that drilling improves cartilage repair compared to microfracture.

METHODS
The research protocol was reviewed and approved by an institutional ethics committee for animal research. Trochlear cartilage defects 4 mm x 4 mm were prepared bilaterally in 16 skeletally mature rabbits. Group I animals (N=8) compared deep drill holes (DRL6/I, 6 mm) to shallow drill holes (DRL2/I, 2 mm), and Group II compared microfracture (MFX2/II) to drill (DRL2/II) holes both at 2 mm deep. Animals were sacrificed 3 months post-operatively and defect repair assessed by quantitative histomorphometry and histological scoring. Statistical analyses were performed with use of analysis of variance with repeated measures in Generalized Linear Model, Statistica (version 9.0, Statsoft Inc., USA) with treatment and animal taken as predictors.

RESULTS
Compared to shallow DRL2, deep DRL6 produced a more voluminous repair tissue with a more hyaline character in cartilage defects (Fig. 1A-F). The DRL6 repair tissue had higher % Fill (p=0.015), % Saf O (p=0.125) and % Coll2 (p=0.094), and less % Coll1 (p=0.251) compared to DRL2. The trend of increased Safranin-O stain in DRL6 vs DRL2 was corroborated by O’Driscoll scoring (p=0.106). Improvement in tissue repair due to deep compared to shallow drilling was significant (p=0.021) when the four parameters (higher % Fill, % Saf O, % Coll2 and lower % Coll1) were analyzed together as repeated-measure variables for an aggregate indicator of overall repair quantity and quality (Fig. 1G).

Compared to MFX2, DRL2 elicited generally more repair tissue (p=0.184), higher % GAG (p=0.181) and higher % Coll2 stain (p=0.051) in the repair matrix (Fig. 2A-F). However, a similarly low Coll1 content (around 10 %) was found in the DRL2 vs MFX2 defects. Improvement in tissue repair due to drilling compared to microfracture was trending (p=0.087) when the four histomorphometric parameters were analyzed together as repeated-measure variables for an aggregate indicator of overall repair quantity and quality (Fig. 2G).

DISCUSSION
The present study is the first to investigate the effect of subchondral perforation depth on cartilage repair outcomes, and to directly compare drilling and microfracture techniques. Our results confirmed the hypothesis that deep vs shallow drilling improved repair tissue quantity and quality, which may result from increased access to marrow compartments and a potentially greater variety of cell types for cartilage repair from the deep marrow. A recent clinical study by Mitheofer et al [1] showed that incomplete defect fill was related to a worse outcome. Therefore surgical methods that promote better fill, with a more hyaline character (i.e. deeper marrow stimulation) could have a therapeutic effect. Our results also showed trending evidence that drilling marginally improved cartilage repair compared to microfracture. This finding may be related to distinct acute effects observed where drilling provided access to viable marrow without apparent heat necrosis, while microfracture caused substantial osteocyte necrosis and bone compaction that could potentially restrict marrow access and impede cell recruitment from marrow stroma.

We conclude that specific surgical variants of bone marrow stimulation techniques can influence cartilage repair outcomes in an important manner. Consequently, these results suggest that surgical marrow stimulation procedures could be further optimized in clinical settings to improve repair outcomes.

Figure 1. A-F: Safranin-O/Fast Green staining (A-B) and collagen typing (C-F) of histological sections from Group I bilateral defects comparing deep 6 mm (DRL6) to shallow 2 mm (DRL2) drilling, after 3 months of repair. Bar=1 mm. G: Histomorphometric analyses of soft tissue repair. * significant effect (p<0.05) and † trending (p<0.2) for DRL6 vs DRL2 by repeated measures using General Linear Model with treatment and animal as predictors (N=8). Arrows (A): drill holes.

Figure 2. A-F: Safranin-O/Fast Green staining (A-B) and collagen typing (C-F) of histological sections from Group II bilateral defects comparing drilling (DRL2) to microfracture (MFX2), both perforated at 2 mm depth, after 3 months of repair. Bar=1 mm. G: Histomorphometric analyses of soft tissue repair. # † trending (p<0.2) for DRL2 vs MFX2 by repeated measures using General Linear Model with treatment and animal as predictors (N=8).

REFERENCES