Effect of Marrow Stimulation on the Microarchitecture of the Subchondral Bone - Long-term Analysis in a Preclinical Large Animal Model

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Introduction

Marrow stimulation techniques such as subchondral drilling [1] are clinically important first-line treatment options for symptomatic small chondral defects, but may cause alterations of the subchondral bone [2]. We hypothesized that drilling induces substantial alterations of the microarchitecture of the subchondral bone that persist for a clinically relevant postoperative period in a large animal model.

Methods

Standardized full-thickness chondral defects (4 x 8 mm) in 19 ovine medial femoral condyles were treated by subchondral drilling: six subchondral drill holes were introduced within each defect to a depth of 10.0 mm using a 1.0 mm Kirschner-wire. After six months postoperatively, the condyles were analyzed by micro computed tomography (μCT; Skyscan, Belgium). The formation of subchondral bone cysts and intralesional osteophytes was evaluated. A standardized methodology for the segmentation of the ovine subchondral unit by six different volumes of interest (VOIs) was developed (Fig. 1) and tested for reproducibility. The following μCT indices were determined in all VOIs: bone mineral density (BMD), bone volume fraction (BV/TV), bone surface/volume ratio (BS/TV), bone surface density (BS/TV), cortical thickness (Ct.Th), trabecular thickness (Tb.Th), trabecular separation (Tb.Sp), trabecular pattern factor (Tb.Pf), trabecular number (Tb.N), structure model index (SMI), degree of anisotropy (DA), and fractal dimension (FD). Zonal microstructural stratification pattern were evaluated in unaffected subarticular spongiosa. To assess the effect of marrow stimulation on the subchondral bone, μCT results of defect areas (SBP-defect and SAS-defect) were compared to adjacent, unaffected bone (SBP-lateral/medial, SAS-lateral/medial). Statistical analysis was performed using the Mann-Whitney-U- and Wilcoxon-test: a value of *p < 0.05* was considered significant.

Results

Six months after arthroscopy and marrow stimulation, no joint effusion, macroscopic inflammation, periarticular osteophyte formation or adhesions were observed. A total of 16 single subchondral bone cysts were detected in 12 condyles (63 % of all specimens) with mean vertical and horizontal diameters of 4.3 and 4.2 mm, respectively. Within five defects, six intralesional osteophytes were detected (26 % of all specimens). Five of the 19 joints (26 %) exhibited neither cysts nor osteophytes. Independent VOI-definition by two investigators yielded similar results for μCT parameters in the unaffected subchondral bone, indicating the good reproducibility of the described method. Analysis of the microarchitecture revealed the absence of zonal stratification patterns in the ovine subarticular spongiosa, permitting an unimpeded analysis of the entire subchondral trabecular network. Drilling induced significant alterations in nearly all parameters for the microarchitecture of the subchondral bone plate and the subarticular spongiosa (Table 1), most importantly in bone mineral density and bone volume (BMD and BV/TV; Fig. 2), bone surface/volume ratio (BS/TV), trabecular thickness, separation and pattern factor (Tb.Th, Tb.Sp, Tb.Pf; all *p < 0.01*) compared to the adjacent unaffected subchondral bone.

Discussion

The ovine subchondral bone can be reliably evaluated using μCT with standardized VOIs. The data further show that subchondral drilling deteriorates the microarchitecture both of the subchondral bone plate and subarticular spongiosa and decreases BMD in a preclinical large animal model. These results suggest that the entire osteochondral unit is altered following marrow stimulation for an extended postoperative period.

Significance

The subchondral bone remains fragile after marrow stimulation for longer durations than previously expected.

References


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