INTRODUCTION: The Reamer Irrigator aspirator (RIA) was initially designed to avoid complications due to fat embolism during reaming procedures (Pape et al 2005). However, surgeons soon realized that the RIA system had further uses. The reamer of the RIA system has been investigated for the treatment of intramedullary infections (Zalavras & Sirkin 2010), the collection of autologous bone grafts (Belthour et al. 2008) and more recently the collection of cells (Porter et al. 2008). In all cases the RIA has shown promising results. Indeed, for autograft collection it is indicated in cases where insufficient iliac crest bone is available following an initial surgery (Newman 2008). This leads to the question, if a patient requires additional treatments following treatment with bone graft material, as was indicated by Newman (2008), would it be possible to re-harvest from the intramedullary canal? In this study it was hypothesized that, if necessary, it would be possible to re-harvest bone from the intramedullary canal.

METHODS: Six female Swiss alpine white sheep aged (2-4 years old) were included in this study under the approval of the local governmental animal use committee. In each animal one tibia was reamed with a RIA device under fluoroscopic guidance using progressively smaller reamer heads (15 mm to 12 mm) to avoid injury to the outer cortex of the tibia. Reaming progressed distally into the isthmus of the tibia up to a mean distance of 11.8 cm (± 2.5 cm). In vivo evaluation consisted of monthly radiographs and intravital fluorochrome labels at weeks 3, 6 and 9. The animals were euthanized 12 weeks post surgery and both tibias were collected, scanned using high-resolution peripheral quantitative computed tomography (HR-pQCT, XtremeCT, Scanco Medical, Switzerland), and processed for uncalcified histological analysis. Ex vivo analysis was performed in 2 defined regions of interest (ROI) of 3 cm in length, in the metaphyseal (M-ROI) and diaphyseal (D-ROI) regions of the tibia (Fig. 1). For statistical analysis after checking the data for normality, a paired student-t-test was utilized to compare the reamed and unreamed bone using statistical software (Minitab version 16, Minitab Inc. USA). Differences between groups were considered significant when p ≤ 0.05.

RESULTS: In vivo bone formation was assessed using monthly radiographs. From these radiographs no in vivo complications were observed. In vivo radiographs did indicate some bone formation; however the most distal point of reaming was clearly visible at all-time points analyzed.

From HR-pQCT data, it was found that in the D-ROI there was no statistically significant difference in the total bone volume (TBV) of the reamed and contralateral tibiae (p = 0.643). However, there was a significant increase in new bone volume (NBV) in the reamed limbs, (p = 0.035). This increase in NBV in the reamed limbs corresponded with a statistically significant decrease in total bone density (TBD) in comparison to the contralateral un-reamed limb. In the M-ROI, no statistically significant differences between the reamed and contralateral tibiae were detected in TBV, TBD or NBV (p ≥ 0.358). No differences were detected in the new bone density (NBD) in either ROI (p ≥ 0.626). Histological analysis of the un-reamed bones showed a bone marrow cavity predominantly consisting of large amounts of univacular white fatty tissue (Fig. 2). There was a slight to moderate number of trabeculae in the D-ROI. There were no trabeculae in the D-ROI. In contrast, in the reamed tibia a slight to moderate formation of mesenchymal fibrous connective tissue was recorded in reamed areas, which indicates reparation of the iatrogenic insult (Fig. 2). Additionally, a minimal to slight deposition of hemosiderin in reamed areas was a residue of previous haemorrhages. The reamed bone marrow cavity predominantly consisted of large amounts of univacular white fatty tissue. It appeared that multifocal trabecular fragments caused by reaming had sometimes been dislocated to more distal areas. These fragments were largely viable, as characterized by strong signs of bone remodeling, especially during the last 3 weeks before necropsy (strong fluorescence). Moreover, these fragments show only minimal signs of osteolysis (formation of osteocytic lacunae) and slight osteoclastic activity (irregular edges). At least in one animal, there were clear signs of new bone formation at the endosteal area of the D-ROI (as opposed to dislocated reamings). Furthermore, there was an increase of bone remodeling in the cortical bone D-ROI.

DISCUSSION: In this study the in vivo radiographs did not indicate any major new bone formation. However, radiographs are only capable of detecting highly mineralized bone and it is possible that new bone did form but was not sufficiently mineralized to be detected using this technique.

It should be noted that it is difficult to evaluate the accuracy of the threshold when analyzing new bone formation using HR-pQCT, due to limitations of the image quality. Nevertheless, from bone volume and bone density measurements using HR-pQCT, it was found that in the D-ROI there was no difference in the TBV of the reamed tibia in comparison to the contralateral tibia. However, when only new bone was considered, there was significantly more bone in the reamed tibia when compared to the un-reamed tibia. This indicates that new bone formation has taken place to such an extent that there is no difference in the total bone in the D-ROI. However, a considerable amount of bone in the reamed tibia is newly formed immature bone. This was further indicated by the fact that the TBD of the reamed tibia is significantly lower than that of the un-reamed tibia, since new bone has a lower density than mature remodeled cortical bone. In the M-ROI no significant differences were detected in terms of bone volume or bone density in either ROI or using either threshold.

In review of the histological sections, slight grade new bone formation was confirmed in the D-ROI of at least 4 of 6 tibias assessed. While the reamed bone had not returned to normal 3 months post-surgery, there was evidence that this process was ongoing. Bone remodeling was observed in areas where new bone formation had occurred, nevertheless, the majority of this bone was immature. In conclusion, new bone formation has occurred in the reamed tibiae of sheep 3 months post RIA reaming. The total bone volume of the reamed tibiae is comparable to that of the contralateral un-reamed tibiae. However, since cortical thinning was observed radiographically even 12 weeks post-surgery, extreme care should be taken not to create further thinning of the cortex during a subsequent reaming procedure.

SIGNIFICANCE: In cases where the patient bone quality is poor, surgeons sometimes have difficulty harvesting sufficient autologous bone for grafting. The results of the current study indicate that bone regeneration post reaming may be sufficient to allow the surgeon to use the intramedullary canal for a re-reaming procedure.

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