INTRODUCTION: The short and long term fate of soft tissue graft ACL reconstruction relies on a proper osseous graft incorporation. Using conventional extracortical fixation techniques, the tendon-to-bone healing progresses via the development of a fibrous interzone (FIZ) which results in an indirect, periosteal-like insertion site (1). The original ACL insertion, however, is characterized as a direct ligament insertion with a transition zone consisting of mineralized and fibrocartilage. A direct insertion may be more appropriate to transmit tensile forces between the ligament tissue and the underlying bone (2). In contrast, an anatomic interference fit fixation of soft tissue grafts may reduce graft-tunnel motion, thus eliminating a tunnel enlargement. Therefore, it has been suggested that anatomic interference fit fixation promotes tendon-to-bone healing, resulting in the development of a direct type of ligament insertion (3). To test the hypothesis that different healing patterns apply for different soft tissue graft fixation techniques we studied the tendon-to-bone healing histologically in an intrarticular model of soft tissue graft ACL reconstruction using extracortical and anatomic graft fixation.

MATERIAL & METHODS: 36 mature sheep underwent open ACL replacement surgery using an ipsilateral flexor tendon graft (4). Animals were followed for 6, 12, and 24 weeks. ACL reconstructions were either performed with anatomic interference fit (IF) fixation using biodegradable interference screws or extracortical with Endobutton/polyester suture (ES) fixation. After sacrifice proximal tibiae and distal femora were harvested and embedded into a polyethylene block with anatomic interference fit fixation specimens of the present one, the intratunnel healing progresses only partially via the development of a FIZ. Furthermore, the development of Sharpey-like fibers, which has been viewed as an integral part of osseous graft incorporation, was only present at sites were a FIZ developed (Fig. 1). At the tunnel aperture site there was a first blending of graft tissue and mineralized cartilage at 12 weeks (Fig. 2). At 24 weeks a broad direct ligament insertion consisting of mineralized and fibrocartilage was found to be developed in all tibial and femoral specimens (Fig. 3). In contrast, with ES fixation there was a broad FIZ present at all time points and was found to be developed in all tibial and femoral specimens (Fig. 3). In contrast, with ES fixation there was a broad FIZ present at all time points and an obvious tunnel enlargement was found. The tunnel enlargement was maximaly pronounced on the femur reaching an increase of +106 % at 6 weeks and a subsequent narrowing (+60 %) at 24 weeks (Fig. 4). At 24 weeks a direct ligament insertion with a mineralized cartilage tidemark was developed in non of the specimens at the femur and partially in 4 out of 6 at the tibia.

DISCUSSION: To our knowledge, this is the first report describing the occurrence of a direct type of ligament insertion after soft tissue graft ACL reconstruction consisting of 4 distinct zones: bone, mineralized cartilage, fibrocartilage, and ligament. In contrast to previous studies and the ES fixation specimens of the present one, the intratunnel healing progresses only partially via the development of a FIZ. Furthermore, the development of Sharpey-like fibers, which has been viewed as an integral part of osseous graft incorporation, was only present at sites were a FIZ has developed. Thus, we conclude, that two different healing patterns may be found during tendon-to-bone healing. The early intratunnel healing and the later surface healing which results in a direct ligament insertion at the articular aperture site. We further found that in extracortical soft tissue graft fixation a direct ligament insertion on the femur did not develop and only partially at the tibia. This may be due to extensive graft-tunnel motions which has been described to occur with extracortical linkage fixation (5). In contrast to ES fixation, there was no tunnel enlargement with IF fixation. It may be reasonable to suggest, that anatomic interference fit fixation reduces graft-tunnel motion and may additionally seal the tunnel aperture site against a synovial inflow, thus preventing tunnel enlargement.

CONCLUSION: There is evidence that anatomic interference fit fixation promotes tendon-to-bone healing by leading to the development of a direct ligament insertion at the joint line, such as it is found with the intact ACL. In contrast to extracortical graft fixation the development of a tunnel enlargement can be prevented as it has recently been demonstrated clinically (6).

FIGURES:

Fig. 1: IF specimen at 6 wks. The graft is in direct contact to the bone. A FIZ is only partially developed. Sharpey-like fibers are present were a FIZ is present.

Fig. 2: IF specimen at 12 wks showing a blending between graft tissue and mineralized cartilage at the articular tibial tunnel site.

Fig. 3: Tibial IF specimen at 24 wks. There is a broad band of mineralized cartilage at the tunnel aperture site indicating the development of a direct ligament insertion at the joint surface.

Fig. 4: Tibial ES specimen at 24 wks showing a severe tunnel enlargement with sclerosis. At the articular aperture site there are first signs of narrowing.

ACKNOWLEDGEMENTS: This study was partially supported by Sulzer Orthopedics Ltd., Baar, Switzerland, Linvatec Corp., Largo, FL, USA, and the Deutsche Forschungsgemeinschaft (DFG We 2233/1-1)

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