Tibial cortical bone remodeling appears evident eight weeks after Achilles tenectomy in rabbits

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INTRODUCTION: Orthopaedic soft tissue reconstructions typically involve the use of tendon autografts. For example, hamstring tendons are commonly harvested not only for use in anterior cruciate ligament reconstruction [1] but also for reconstructing other upper [2] and lower [3] limb tendons and ligaments. Despite routine use of tendon autografts, to date, minimal data exists on the direct effects of tendon harvesting alone (i.e., tenectomy) on the musculoskeletal system. Removing a tendon will alter the distribution and magnitude of joint loading [4], which is compounded further by the substantial donor muscle atrophy occurring after such procedures [4,5]. Thus, tendon autograft surgeries may expose the donor site to undergoing maladaptive structural changes to bone. Therefore, using a rabbit model, we performed a pilot experiment to explore whether signs of bone remodeling would be evident in the rabbit distal tibia 8-weeks after full removal of the Achilles tendon. To date, only cortical bone has been analyzed.

METHODS: Hindlimbs (n = 8) were obtained from four female New Zealand white rabbits that had undergone full unilateral Achilles tenectomy. These rabbits were originally used as control animals in a study investigating the efficacy of artificial tendon replacements that had received ethical approval from The Institutional Animal Care and Use Committee at the University of Tennessee, Knoxville (protocol #2726) for all *in vivo* procedures [6]. Animals were euthanized eight weeks after Achilles tenectomy (~28 wk old at sacrifice). Hindlimbs were fixed in 10% phosphate-buffered formalin for ≥5 d, stored in 70% ethanol, and intact hock joints later imaged in air with an *ex vivo* micro computed tomography scanner (XT H 225, Nikon). Three-dimensional image stacks were reconstructed at 10 µm isotropic voxel size (CT Pro 3D v6.14, Nikon), reoriented in the anatomical plane (DataViewer v1.7.0.1, Bruker), and analyzed using CTAn (v1.23.0.2, Bruker). Axial images were filtered with a Gaussian blur (standard deviation [SD] = 0.5), with cortical bone automatically segmented from the medullary cavity using grayscale-based global thresholding. A 3 mm region with its base 5.3 mm proximal to an anatomical reference point (superior articular surface of the malleolar groove; Figure 1A) [7] was used for extracting cortical bone morphometrics for both the Achilles tenectomized (Figure 1B) and contralateral (Figure 1C) distal tibiae. In addition to total porosity, the number of pores and total pore volume were calculated. The total area within the periosteum (i.e., cortical + medullary), along with cortical bone area, volume, and fraction (% of total area) were also determined. Due to sample size (n = 4 per group), which was limited by the number of specimens available, only descriptive statistics are reported as per guidelines for medical pilot studies [8].

RESULTS: Means, SDs, and individual data points are shown in Figure 2. In the tenectomy limb of all four animals, cortical porosity (mean ± SD of percent change: 114% ± 111%; range of percent change: 12%–272%) and total number of pores (144% ± 131%; 30%–276%) were greater, while total cross-sectional area within the periosteum was smaller (-3% ± 3%; -1% to -8%). In three of the four animals, pore volume was greater (115% ± 137%; -1% to 313%) in the tenectomy limb with lower cortical bone area (-5% ± 8%; -11% to +8%), volume (-5% ± 8%; -11% to +8%), and area fraction (-1% ± 7%; -8% to +9%).

DISCUSSION: Cortical bone remodeling was generally evident in the rabbit distal tibia eight weeks after full Achilles tendon removal. These results suggest that tendon harvesting as autografts may render the donor site prone to undergoing bone maladaptations, potentially leading to poorer bone quality. These alterations may be related to the changes in joint loading seen when a tendon is missing [4]. As average porosity on the contralateral leg exceeded that of previous control limbs [7,9], the between-limb differences reported here may be underestimated due to potential concomitant, compensatory adaptations on the contralateral side. Although we acknowledge that Achilles tenectomies are not performed in clinical practice, the high loading experienced by this tendon provides the worst-case scenario for investigating musculoskeletal outcomes after tendon harvesting (e.g., as autografts). Overall, while statistical inference is limited by the small sample size, these results provide support for more detailed studies focusing on bone and joint adaptations after tenectomy.

SIGNIFICANCE/CLINICAL RELEVANCE: Tendon harvesting for orthopaedic reconstructions may not be as safe of a procedure as long thought. These results may also be relevant for patients with other Achilles-related unloading, such as Achilles tendon rupture.

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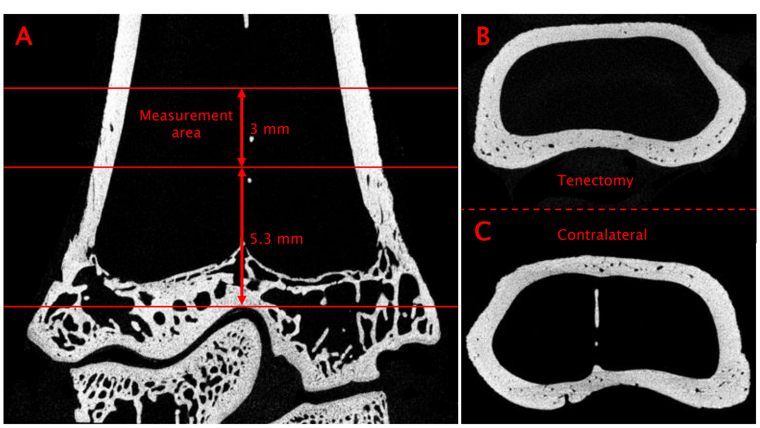

Figure 1. (**A**) Coronal view of the rabbit hock joint with information on analyses superimposed. (**B**) Transverse view of the distal tibia after Achilles tenectomy. (**C**) Transverse view of the contralateral distal tibia. All images are from the same animal, and transverse views are from approximately the same proximodistal location.

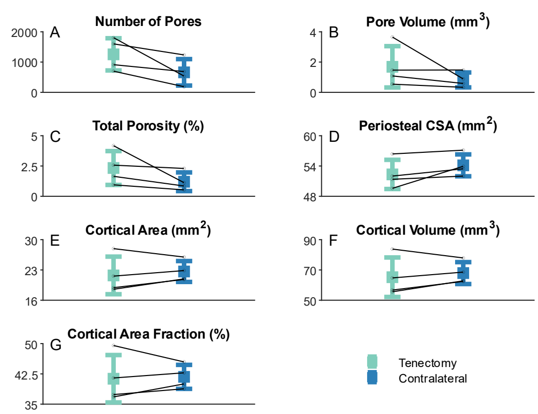

Figure 2. Means, standard deviations, and individual data points for number of pores (**A**), pore volume (**B**), total porosity (**C**), total cross-sectional area (CSA) within the periosteum (**D**), average cortical area (**E**), cortical volume (**F**), and cortical area fraction (**G**).