Rabbit Physeal Fractures Managed with Acute Interpositional Adipose Autograft Does Not Reduce Bar Formation: A 3D Reconstruction Analysis

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INTRODUCTION:
Premature physeal closure after long bone fractures can lead to bar formation and unpredictable growth disturbance. Bar excision has been studied extensively, while data on preemptive tissue interposition into physeal fractures is very limited. A pilot study comparing periosteal and fat autograft interposition in a rabbit physeal fracture model demonstrated a trend towards decreased bar formation with fat interposition. Using the same rabbit model, this study evaluates the physis morphology in 3D, comparing fractures with or without fat autograft interposition to unfractured controls.

METHODS:
Under an approved protocol and IACUC oversight, thirty 10-week-old New Zealand White rabbits underwent induced right proximal tibia physeal fractures. Twenty fractures had retropatellar fat autograft interposed into the physeal fracture (***Fat Group***, n=20) and the remaining fractures had no interposition performed (***Fracture Group***, n=10). The right legs were casted for 10 days and the left legs served as a ***Control Group*** (n=30). Animals returned to normal activity for 6 weeks of growth, then euthanized at 16 weeks of age.

Harvested fresh bilateral proximal tibiae to include proximal 1/3 of tibia were imaged using microCT (SkyScan1076, SkyScan; 36 µm isotropic voxel size, 70kV electrical potential, 141µA current, over 360° rotation with 0.5° step using a 0.5mm aluminum filter). To evaluate the potential effect of the proximal tibia intervention on the distal femoral physis, the first 6 animals had the entire knee (distal 1/3 of femur to proximal 1/3 of tibia) included in the imaging. These images were reconstructed in 3-D and evaluated by a fellowship trained pediatric orthopedic surgeon, blinded to the treatment group, for abnormalities in the distal femoral physis.

Micro CT image sets were analyzed using custom MATLAB (2021a; Mathworks) software. Using the VolumeSegmenter application, regions of interest (ROIs) for each physis were manually demarcated in the sagittal and coronal plane. A binarized mask of the adjacent bony tissue was calculated and subtracted from each ROI to ensure any overlapping voxels or mislabeled voxels were removed. Then, the minimum Feret distance between the superior and inferior surface of the physis was calculated to spatially map thickness in 3D (Figure 1). In addition, the mean surface area and mean volume of each physis was also calculated (Figure 1).

Statistical Analysis: A Generalized Linear Mixed Model was used to analyze each target outcome, with side as a repeated measure and random effect of subject to control for variance contributed by each subject represented in 2 of the groups. Significance was set at $p<0.05$.

RESULTS:
Fat and Fracture groups were not significantly different in age, weight, body length, surgical duration, weight increase, and body length increase over six weeks ($p>0.05$). The Fat group had higher blood loss than the Fracture Group (1.9±0.9ml and 1.1±0.3ml, $p=0.035$).

The six distal femur physes analyzed (2 Fracture, 4 Fat) had no physeal bars nor evidence of growth disturbance of the joint surface was seen on 3D CT reconstructions.

Though the variance of the measures was the least in the Control group, there were no differences between groups in the 3D modeling of physis surface area (Table).

DISCUSSION: We have previously demonstrated that fat interposition into fractures using this same model still may allow the development of physeal bar formation after an acute fracture. This study demonstrates that there are no differences in 3D physis appearance (surface area, thickness, or volume) between a proximal tibial physeal fracture managed with reduction alone or with reduction following fat tissue interposition. However, these 3D values were not significantly different between the fractured tibia and the non-injured tibia; suggesting that variation in thickness, volume, and surface area may alter in both directions with a fracture (thinner and thicker in places) to remain measurably similar to normal as a mean value.

SIGNIFICANCE/CLINICAL RELEVANCE: It is clear via gross 3D evaluation of surface area and Feret thickness that a fracture through the proximal tibial physis may result in a clinically significant disruption of the physis whether managed via acute fat interposition or not. However, future studies will be important to determine the significance in the variation between thinning and thickening of the fractured physis, including histologic analysis of those areas.

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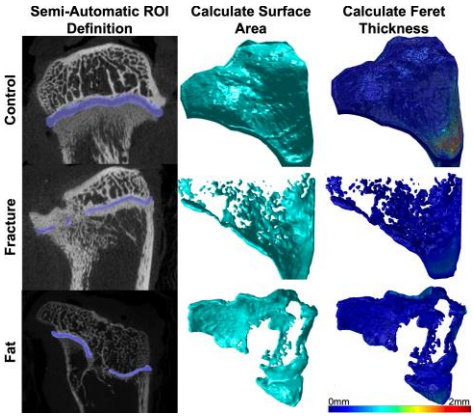

Group	n	Thickness (mm) mean	Thickness (mm) stdev	Surface area (mm^2) mean	Surface area (mm^2) stdev	Volume (mL) mean	Volume (mL) stdev
Control	30	0.546	0.119	260.7	13.8	0.125	0.026
Fracture	10	0.470	0.225	226.3	108.4	0.112	0.101
Fat	20	0.724	0.419	278.2	66.7	0.172	0.107
p-value		0.121		0.275		0.122	