3D Joint Space Width Measures from Weight Bearing CT Detect Early Degenerative Joint Changes

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Introduction

- Monitoring of early joint degeneration after intra-articular fracture treatment is challenging
- Traditionally, categorical grading scales based on plain radiographs, such as the Kellgren-Lawrence grade, have been used.
- These scales have proven insensitive to all but the latest stages in the disease process.
- Recently, weight bearing CTs (WBCTs) have become available clinically to measure joint space width (JSW) (Figure 1).

Figure 1. pedCAT weight bearing CT scanner.

- JSW measurements have demonstrated promise in providing more reliable, continuous data on joint degeneration.
- Clinically, JSW is measured manually in a single plane from these inherently 3D data, discarding much of the feature rich data from such scans.

Objective

- More fully investigate value of WBCTs by measuring 3D JSW across the entire joint surface.

Methods

- 15 patients with operatively managed tibial pilon fractures from two institutions were enrolled in this IRB-approved study.
- Patients were treated by 4 fellowship-trained orthopaedic trauma surgeons.
- Weight-bearing ankle CT scans at an isotropic 0.37 mm resolution (pedCAT; CurveBeam, LLC) were acquired 6 months after the injury.
- 3D models of the tibiotalar joint were created using a semi-automated segmentation protocol.
- The joint space was split into 9 discrete and clinically relevant regions using a 3-by-3 grid from anterior to posterior and medial to lateral.
- The talar surface was utilized as an intact reference from which to measure.

Results

- Mean 3D JSW was insignificantly smaller on the injured side for 11/15 ankles (Table 1)

Table 1. Change in minimum distance (top) and variance (bottom) in each region from intact to fractured ankle.

ΔMin (mm)	**Region**	**1**	**2**	**3**
	Avg ± SD	-.69 ± .76	-.28 ± .71	-.40 ± .71
		4	**5**	**6**
		-.66 ± .75	-.49 ± .86	-.74 ± .79
		7	**8**	**9**
		-.29 ± .90	-.11 ± .77	-.54 ± .80
ΔVar (mm^2)	**Region**	**1**	**2**	**3**
	Avg ± SD	.17 ± .24	.10 ± .17	.10 ± .09
		4	**5**	**6**
		.14 ± .18	.14 ± .16	.18 ± .27
		7	**8**	**9**
		.12 ± .13	.09 ± .17	.10 ± .17

- Minimum 3D JSW was significantly smaller on the injured side for 12/15 patients.
  - 0.6±0.5mm injured vs. 1.3±0.4mm uninjured contralateral; p<0.001
- Variance in 3D JSW was significantly larger on the injured side for 13/15 patients
  - 0.7±0.4mm injured vs. 0.4±0.3mm uninjured contralateral; p<0.001
- Minimum 3D JSW was significantly smaller on the injured side for six of the nine regions (p<0.05) (Figure 2)

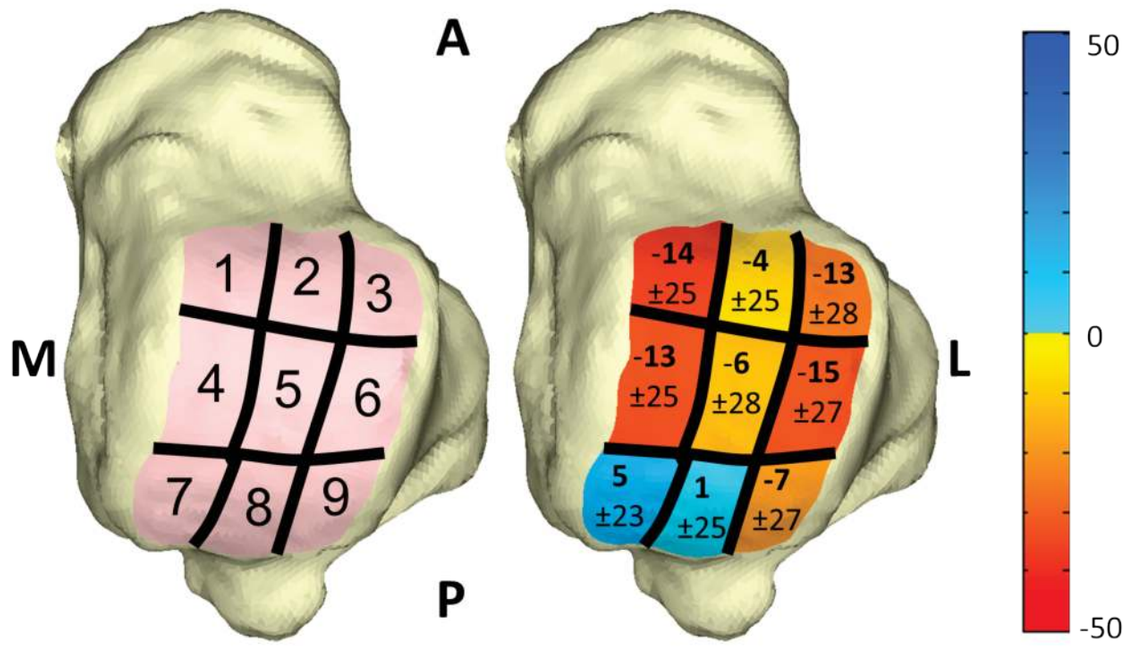

Figure 2. Left, 3x3 grid with numbering. Right, percent difference in minimum JSW between intact and fractured ankles.

- Mean 3D JSW was not significantly different for any of the 9 regions.
- Difference in variation in the joint was at least 120% greater for the injured ankles compared to their uninjured counterparts.

Discussion

- 3D JSW measures provide insight into both the location and magnitude of joint space narrowing as well as obvious signs of surface incongruity, like increases in JSW variability.
- Significant differences were seen using minimum, but not mean, 3D JSW.
- Interestingly, significant differences were also found when comparing the JSW variability within each region to the intact ankle.
- These findings support the notion that data from WBCT scans are sensitive to early changes in the joint, in this case, within 6 months post-operatively.
- Future work will evaluate the ability of these measures to track longitudinal degeneration as the joint space potentially further narrows over time following pilon fracture.

Significance

- Traditional techniques to assess joint degeneration have proven insensitive to all but latest stages in the disease process.
- WBCTs enable 3D JSW analysis that can detect early degenerative changes associated with PTOA as soon as 6 months following operative treatment of tibial pilon fractures.

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