The Journal of Foot & Ankle Surgery ■■ (2017) ■■–■■

Contents lists available at ScienceDirect

The Journal of Foot & Ankle Surgery

journal homepage: www.jfas.org

Original Research

Cross-Sectional Area Measurement of the Central Tarsometatarsal Articulation: A Review of Computed Tomography Scans

John Randolph Clements, DPM [1], Kelley Whitmer, MD [2], Hoa Nguyen, MD [3], Matthew Rich, MD [3]

[1]*Attending Physician, Department of Orthopaedics, Virginia Tech Carilion School of Medicine, Roanoke, VA*
[2]*Radiologist, Department of Orthopaedics, Virginia Tech Carilion School of Medicine, Roanoke, VA*
[3]*Resident, Department of Orthopaedics, Virginia Tech Carilion School of Medicine, Roanoke, VA*

A R T I C L E I N F O

Level of Clinical Evidence: 2

Keywords:
arthrodesis
fracture
fusion
ligamentous Lisfranc injury
open reduction internal fixation
tarsometatarsal surface area

A B S T R A C T

Currently, disagreement exists regarding the superior method for repairing a ligamentous Lisfranc injury regarding whether to use arthrodesis or open reduction internal fixation. The 2 procedures differ in the amount of articular cartilage destroyed. Arthrodesis removes all the articular cartilage, and open reduction internal fixation places transarticular screws, essentially destroying a portion of cartilage. We performed a review of 30 consecutive computed tomography scans that included both foot length and undamaged first, second, and third tarsometatarsal joints to quantify the amount of articular surface area destroyed by placement of standardized 4-mm diameter screws. Measurements were performed using a freeform tool. The calculated surface area of the screws was subtracted from the measured surface area of the joint to yield the amount of surface area occupied by the screws. Our results demonstrated that the average amount of articular surface area destroyed in the first, second, and third tarsometatarsal joints was 4.87%, 4.79%, and 4.86% respectively, with a standard deviation of <1% for each of the joints. Our results have demonstrated that screw placement accounts for only a small percentage of articular surface destroyed. They also showed that the articular surface damage was comparable among the first 3 tarsometatarsal joints. Additionally, our results were similar to the articular surface area calculated from cadaveric specimens in a previous biomechanical study, demonstrating that computed tomography can allow for reliable and accurate assessments of articular surface areas in the foot.

The Lisfranc joints constitute the bony structural support of the transverse arch in the midfoot and account for roughly 0.2% of all fractures (1). Lisfranc injuries vary in their etiology, from ligamentous injuries to osseous injuries to injuries involving the articular surface. The variability in etiology can lead to difficulties in the diagnosis, with some fractures remaining undiagnosed. If untreated, a Lisfranc fracture can lead to long-term discomfort and disability. Two main surgical remedies are available for repair. The first is open reduction internal fixation (ORIF). The procedure itself involves exposure of the fracture, reduction of displaced bones, and implantation of screws, which can vary in size from 3.5 to 4.5 mm (2). The second is primary fusion of the joint. Primary fusion uses a very similar technique in that the disarticulated bones are reduced and screws are implanted to hold the joint in place. Fusion differs from internal fixation by removal of the articular cartilage from the opposing surface of the joints (3). Removal of the cartilage prepares the bone for fusion.

Financial Disclosure: None reported.
Conflict of Interest: None reported.

Address correspondence to: John Randolph Clements, DPM, Department of Orthopaedics, Virginia Tech Carilion School of Medicine, Three Riverside Circle, Roanoke, VA 24014
E-mail address: jrclements@carilionclinic.org (J.R. Clements).

Currently, the 2 types of repair for Lisfranc fractures offer physicians the option of either attempting internal fixation primarily or using fusion primarily. Herein lies the controversy surrounding the repair of Lisfranc injuries. The circumstances in which the controversy exists include the treatment of patients with extensive articular damage with multiple joint fragments and the treatment of those with complete isolated ligamentous disruption (4). Two arguments exist for the use of primary fusion versus ORIF for these injuries. First, purely ligamentous injuries have not always healed after ORIF, resulting in an increased incidence of in joint degeneration (4). Second, ≤94% of patients will develop arthritis later after ORIF and require secondary fusion (4). We sought to determine why the ORIF approach to primarily ligamentous Lisfranc injuries tends to require subsequent secondary fusion.

For our study, we hypothesized that screw placement during the ORIF procedure would lead to significant damage to the articular surface, potentially accounting for the incidence of arthrodesis requiring secondary fusion. The primary aim of our study was to use computed tomography (CT) scans to measure the articular surface of the first 3 tarsometatarsal (TMT) joints and subtract from that the surface area of the head of the screws used during fixation. We performed a review of foot and ankle CT scans to determine whether screw placement damaged the articular surface.

1067-2516/$ - see front matter
https://doi.org/10.1053/j.jfas.2017.12.017

Table 1
Power table for Cohen's d

n	Cohen's d Effect Size															
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6
3	0.032	0.041	0.052	0.065	0.079	0.095	0.113	0.133	0.155	0.179	0.204	0.23	0.258	0.287	0.316	0.347
4	0.035	0.048	0.064	0.084	0.108	0.136	0.169	0.205	0.245	0.289	0.335	0.383	0.433	0.483	0.533	0.582
5	0.037	0.054	0.076	0.104	0.138	0.18	0.227	0.281	0.339	0.401	0.466	0.53	0.594	0.654	0.711	0.762
6	0.039	0.06	0.088	0.124	0.169	0.224	0.286	0.356	0.43	0.507	0.538	0.655	0.722	0.781	0.833	0.875
7	0.041	0.066	0.099	0.1144	0.2	0.268	0.345	0.428	0.515	0.6	0.681	0.754	0.816	0.867	0.908	0.938
8	0.043	0.071	0.111	0.164	0.231	0.311	0.401	0.496	0.591	0.681	0.761	0.828	0.882	0.922	0.951	0.971
9	0.045	0.077	0.122	0.184	0.262	0.354	0.455	0.559	0.659	0.748	0.823	0.882	0.925	0.955	0.975	0.986
10	0.047	0.082	0.134	0.204	0.293	0.396	0.506	0.616	0.717	0.803	0.871	0.92	0.954	0.975	0.987	0.994
11	0.049	0.087	0.145	0.224	0.323	0.436	0.554	0.668	0.767	0.848	0.907	0.947	0.972	0.986	0.994	0.997
12	0.05	0.092	0.156	0.244	0.353	0.475	0.599	0.714	0.81	0.883	0.933	0.965	0.983	0.993	0.997	0.999
13	0.052	0.098	0.168	0.264	0.382	0.512	0.64	0.754	0.845	0.911	0.953	0.977	0.99	0.996	0.999	>0.999
14	0.053	0.103	0.179	0.283	0.41	0.547	0.678	0.79	0.875	0.932	0.967	0.985	0.994	0.998	0.999	>0.999
15	0.055	0.108	0.19	0.303	0.438	0.58	0.713	0.821	0.899	0.949	0.977	0.991	0.997	0.999	>0.999	>0.999
16	0.057	0.113	0.202	0.322	0.465	0.612	0.745	0.848	0.919	0.962	0.984	0.994	0.998	0.999	>0.999	>0.999

Materials and Methods

The institutional review board approved our review of CT scans of the foot. We calculated the theoretical amount of articular surface area occupied by the screws implanted during ORIF. No direct patient interaction occurred, and the patients did not receive additional services or compensation on completion of the present study.

A power analysis was performed by the Laboratory for Interdisciplinary Statistical Analysis at Virginia Polytechnic Institute. A sample size of 10 was considered to provide a mean articular surface area of each joint for reference when calculating our desired sample size. In performing the power analysis, we defined our control group as TMT joints without screw placement and our treatment group as TMT joints with screw placement typical of an ORIF procedure. We reasoned that our control group would effectively have 0% articular damage and our treatment group would effectively have >0% articular damage. We further reasoned that because we would be comparing the articular damage of our treatment group to a mean articular damage of 0% in the control group, we would always see a large effect size. A Cohen's d was calculated using the mean articular damage of the treatment group and the control group. We referred to the power table for Cohen's d to determine our sample size. With a Cohen's d of >1.60 for the mean all 3 of our TMT joint surface areas and a desired power of >0.99, we required a sample size of <12 (Table 1). Given the abundance of CT images available and our small required sample size, we increased our actual sample size to 30.

The CT scans imaged using 1 machine from January 1, 2014 to April 1, 2014 were consecutively reviewed, starting with the most recent scan and subsequently previous dates to identify CT scans that fit the predetermined inclusion criteria. The inclusion criteria included CT scans of the visible first, second, and third TMT (TMT1, TMT2, TMT3, respectively) joints deemed by a single radiologist (K.K.W.) to not have been significantly violated by trauma, infection, or arthritis to allow for measurement of the articular surface areas. In addition, the foot length had to be assessable on the same CT scan or an accompanying radiograph.

Each TMT joint was reconstructed into a series of images by taking 10 to 25 cross-sectional images spanning the metatarsal to the cuneiform side of the joint (Fig. 1). Both the articular surface areas and the foot sizes were measured using a freeform tool and recorded to 100th of 1 mm (Fig. 2). All reconstructions and measurements were performed by 1 of us (H.N.) to reduce user error and variability. The percentage of the articulating joint surface area destroyed by screw placement was calculated (H.N.) using the following equation:

$$\% \text{ Area destroyed} = 100 \times (24.32 \times \#\text{screws in joint/articular surface area})$$

The screws had a fixed diameter of 4 mm. Using r^2, we calculated a surface area of 12.16 mm^2 per pass of 1 screw. Each screw passed once through the metatarsal side and once through the cuneiform side, effectively requiring 24.32 mm^2/screw. Additionally, the number of screws per joint space differed among the joints examined. Two screws were typically placed in the first TMT, with 1 screw each placed in the second and third TMT joints. The articular surface area was the summation of the measured metatarsal and cuneiform articulating surface areas.

The percentage of articulating joint surface area destroyed was calculated for each joint on every CT scan. Additionally, the mean percentage for each joint and the sample standard deviation were calculated. The percentages were also cross-referenced with the associated foot sizes.

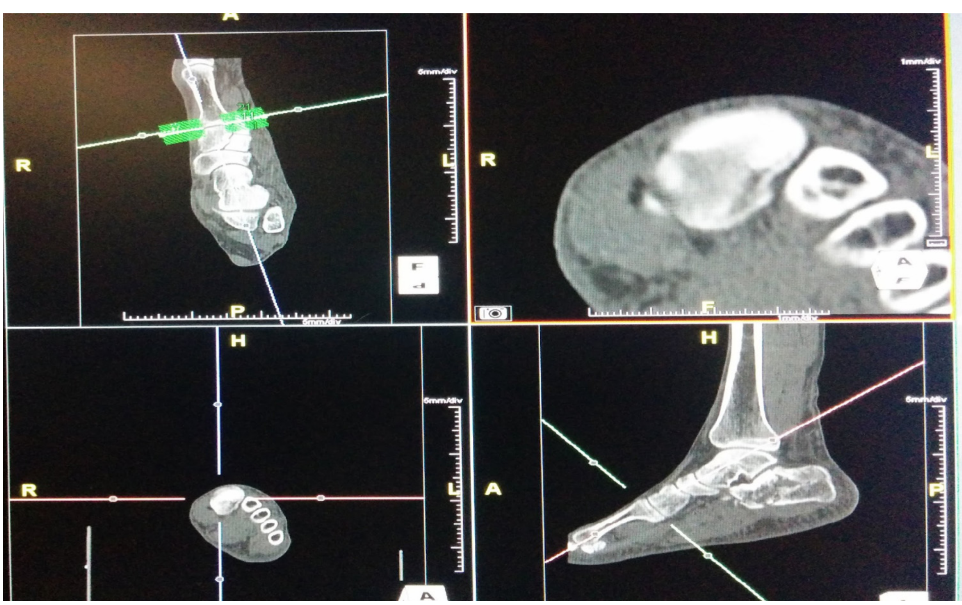

Fig. 1. Two-dimensional planar reconstruction.