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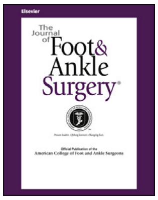

Biomechanical Comparison of Fixation With a Single Screw Versus Two Kirschner Wires in Distal Chevron Osteotomies of the First Metatarsal: A Cadaver Study

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ABSTRACT

Distal chevron osteotomy is a common procedure for surgical correction of hallux valgus. Osteosynthesis with 1 screw or 2 Kirschner wires has been commonly used. We compared the stability of the 2 techniques in distal chevron osteotomy. Sixteen first metatarsals from fresh-frozen human cadaver feet (9 different cadaveric specimens) were used. A standardized distal chevron osteotomy was performed. One first metatarsal from each pair was assigned to group 1 (3.5-mm cortical screw; n = 8) and one to group 2 (two 1.6-mm Kirschner wires; n = 8). Using a materials testing machine, the head of the first metatarsals was loaded in 2 different configurations (cantilever and physiologic) in succession. In the cantilever configuration, the relative stiffness of the osteosynthesis compared with intact bone was 59% ± 27% in group 1 and 68% ± 18% in group 2 ($p = .50$). In the physiologic configuration, it was 38% ± 25% in group 1 and 35% ± 7% in group 2 ($p = .75$). The failure strength in the cantilever configuration was 187 ± 105 N in group 1 and 259 ± 71 N in group 2 ($p = .21$). No statistically significant differences were found in stability between the 2 techniques. The use of 1 screw or 2 Kirschner wires had no significant differences in their biomechanical loading capacity for osteosynthesis in distal chevron osteotomies for treatment of hallux valgus.

Hallux valgus is a common foot deformity. Many conservative and surgical treatment options are available for hallux valgus. Surgical treatment should be reserved for severe deformities. Many different osteotomies of the first metatarsal have been described for surgical correction of hallux valgus (1–5).

In 1979, Johnson et al (6) reported the results for 18 patients who had undergone chevron osteotomy for surgical correction of hallux valgus at the Mayo Clinic. In 1981, Austin et al (7) described a V-shaped displacement osteotomy of the metatarsal head for hallux valgus and metatarsus primus varus. To date, the chevron osteotomy with minor modifications has been one of the most frequently used and widely accepted operations for treating hallux valgus. Initially, no fixation was performed after chevron osteotomy (7). Today, various fixation methods are used, including screws, Kirschner wires, absorbable pins, staples, and plates. The choice of fixation method is often determined by surgeon preference.

In a retrospective study, Armstrong et al (8) reviewed the data from 69 patients who had undergone distal chevron osteotomy and fixation with a Kirschner wire or cortical screw. Shorter operating times were noted in the Kirschner wire group, but no differences were found in postoperative range of motion, infection rate, or pseudarthrosis rate.

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In a study by Crosby and Bozarth (9), no differences were found in patient satisfaction or improvement of the hallux valgus angle in 17 patients who had undergone distal chevron osteotomy and fixation with a screw or Kirschner wire or without an implant.

Several biomechanical studies comparing the initial stability of different implants in distal chevron osteotomy have been reported. Buckenberger and Goldman (10) found that a plate and a Kirschner wire were able to resist displacement in distal chevron osteotomy in vitro. Dalton et al (11) compared plantar and dorsal orientation of a screw or Kirschner wire, different sizes of Kirschner wires, and a tension-band effect in polyurethane foam models and human cadavers. A plantar Kirschner wire was found to be the most stable construct in the polyurethane foam models, and a dorsal Kirschner wire with a synthetic tension band was the most stable in the cadaver specimens (11). Gonda et al (12) reported that a plantar-directed Kirschner wire led to greater stability than a dorsally directed one. Jacobson et al (13) compared 1 or 2 screws of different sizes with a construct consisting of a screw and Kirschner wire in distal chevron osteotomy and observed the strongest fixation with the screw–Kirschner wire construct. In a study by Khuri et al (14), in contrast, no differences in stability were noted between 2 screws of different sizes and a construct consisting of a screw and Kirschner wire.

In 2 recent clinical studies comparing proximal and distal chevron osteotomy, 2 Kirschner wires were used for fixation (15,16). The investigators obtained good clinical results with this fixation method. To the best of our knowledge, no biomechanical studies have been reported that investigated the stability of 2 Kirschner wires in distal chevron osteotomy in vitro.

The aim of the present biomechanical study was to determine whether any differences were present in stability between 1 screw and 2 Kirschner wires used for fixation of a distal chevron osteotomy. We hypothesized that no differences would be found in stability between the 2 methods. The primary aim was to measure the failure load, and a secondary aim was to compare the stiffness of the 2 constructs. We performed a biomechanical study with fresh-frozen human cadavers to compare 1 screw versus 2 Kirschner wires for fixation of distal chevron osteotomy.

Materials and Methods

The study was conducted with approval of the local ethics committee (approval no. 15-358). Nine matched pairs of fresh -frozen human cadaver feet were used for the study (Table 1). Six of the donors were male and three were female. The donors' mean age was 77 (range 61 to 89) years. The bone mineral density in each specimen was measured in the posterior third of the calcaneus using dual X-ray absorptiometry (Lunar iDXA; GE Healthcare, Chicago, IL) (17,18). Radiographs of the specimens in dorsoplantar and lateral projections were taken to exclude any osseous pathology. Of the 18 specimens, 2 had to be excluded owing to deformation at the head of the first metatarsal.

All soft tissues were removed. The specimens were wrapped in saline-soaked compresses and stored at −20°C before the experiments. The first metatarsals used in the study had an average length of 6.4 (range 6.1 to 6.9) cm. For the experiments, the specimens were thawed at room temperature for 12 hours. The base of each first metatarsal was embedded perpendicularly in cold curing resin to a depth of 2 cm (Technovit® 4004; Heraeus Kulzer GmbH, Wehrheim, Germany) to achieve stable fixation in the materials testing machine.

Table 1
Study population

Specimen No.	Age (y)	Sex	Fixation Method	
			Right First Metatarsal	Left First Metatarsal
1	86	Female	2 Kirschner wires	1 Screw
2	73	Male	2 Kirschner wires	1 Screw
3	73	Female	2 Kirschner wires	1 Screw
4	79	Male	2 Kirschner wires	1 Screw
5	89	Male	1 Screw	2 Kirschner wires
6	68	Male	1 Screw	Excluded
7	61	Male	Excluded	2 Kirschner wires
8	81	Male	1 Screw	2 Kirschner wires
9	85	Female	1 Screw	2 Kirschner wires

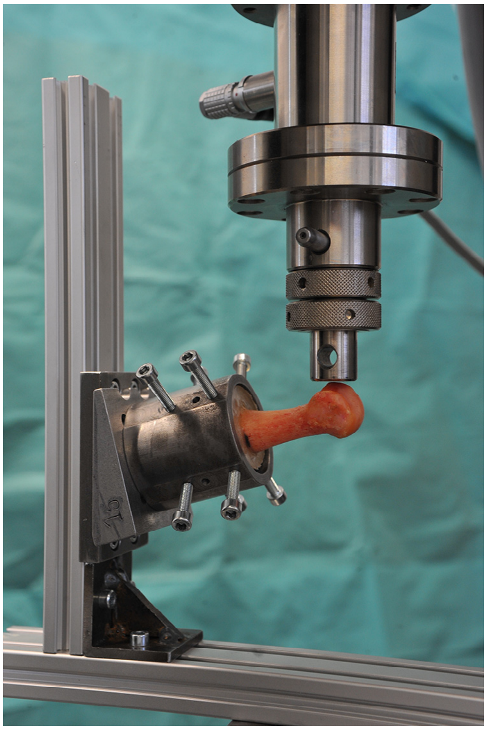
Fig. 1. The experimental setup for cantilever testing.

Each specimen was tested in 2 loading configurations, in accordance with the method described by Favre et al (2): cantilever (Fig. 1) and physiologic (Fig. 2). In the cantilever configuration, the first metatarsal was positioned with an angle of 15° between the axis of the first metatarsal and a horizontal line. A load in the plantar-to-dorsal direction was applied to the head of the first metatarsal. The cantilever configuration represents the most frequently used and well-established experimental set-up for biomechanical investigation of osteotomies of the first metatarsal (1–5,14,19–23). It simulates the anatomic position of the first metatarsal during standing and investigates the effect of the ground reaction force.

Muscular contraction during walking creates a force that cannot be measured in the cantilever configuration. Favre et al (2), therefore, introduced a second arrangement for the first metatarsal in materials testing machines, the physiologic configuration. Jacob (24) estimated the amounts of ground reaction and muscular force acting at the first metatarsophalangeal joint and concluded that the force acts at an angle of 13° to the axis of the first metatarsal. This angle was used by Favre et al (2) in the physiologic configuration.

In the present study, load was applied to the head of each first metatarsal with a materials testing machine (model no. Z010; Zwick Roell, Ulm, Germany) at a displacement rate of 2 mm/min (2). The preload was 5 N. The maximum load applied to intact bones was 150 N in the cantilever configuration and 550 N in the physiologic configuration (2). Damage to the first metatarsals was avoided with these loads. Load displacement curves were recorded, and the stiffness of the intact first metatarsals was calculated.

After testing the intact first metatarsals, distal chevron osteotomies were performed by the first author (M.T.) in accordance with the method described by Favre et al (2). The apex of the osteotomy was located at the center of the metatarsal head, 10 mm proximal to the metatarsophalangeal joint line. The angle of the distal chevron osteotomy was 70°, with the 2 arms equal in length (Fig. 3). The osteotomy was performed with a 0.6-mm saw blade. The distal fragment was moved 5 mm laterally.

One first metatarsal from each pair was assigned to group 1 (n = 8). The osteotomy was fixed with one 3.5-mm partially threaded cortical screw (26 mm long, titanium; DePuy Synthes, Zuchwil, Switzerland) using a lag screw technique. The screw hole was drilled with a 2.5-mm spiral drill and positioned from dorsomedially to plantolaterally, with an angle of 10° to 15°. The other first metatarsal from each pair was assigned to group 2 (n = 8). The osteotomy was fixed with two 1.6-mm smooth Kirschner wires in accordance with the methods described by Park et al (15) and Lee