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Effect of Combined Fibular Osteotomy on the Pressure of the Tibiotalar and Talofibular Joints in Supramalleolar Osteotomy of the Ankle: A Cadaveric Study

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ABSTRACT

We investigated the effect of combined fibular osteotomy on the pressure of the tibiotalar and talofibular joints in medial opening-wedge supramalleolar osteotomy. Three different tibial osteotomy gaps (6, 8, and 10 mm) were created in 10 cadaveric models, and the pressure in the tibiotalar and talofibular joints was measured under axial load before and after fibular osteotomy. The heel alignment angle and talar translation ratio were evaluated radiographically. An increase in osteotomy gap led to increases in hindfoot valgus ($p = .001$) and the contact and peak pressures in the talofibular joint ($p = .03$ and $p = .004$). In contrast, the contact and peak pressures in the tibiotalar joint were unchanged with an increasing osteotomy gap ($p = .52$ and $p = .76$). Fibular osteotomy reduced the contact and peak pressures in the talofibular joint ($p < .001$ and $p = .001$, respectively), and it did not influence the contact and peak pressures in the tibiotalar joint ($p = .46$ and $p = .14$, respectively). Therefore, fibular osteotomy might be necessary in supramalleolar osteotomy for medial ankle arthritis to minimize the increase in pressure in the talofibular joint, especially when the osteotomy gap is large.

Supramalleolar osteotomy has been used to treat asymmetric ankle osteoarthritis with a partially preserved tibiotalar joint surface (1,2). Medial opening-wedge supramalleolar osteotomy to treat medial ankle arthritis restores joint orientation and causes a load shift to a portion of the joint that is not involved in the degenerative process, thus, improving ankle function and relieving pain (3–8).

Several clinical studies have reported good results of medial opening-wedge supramalleolar osteotomy with fibular osteotomy for medial ankle arthritis (9,10), but other studies have reported good results with medial opening-wedge supramalleolar osteotomy without fibular osteotomy (11,12). Furthermore, Lee and Cho (13) suggested that their new oblique supramalleolar opening-wedge osteotomy without fibular osteotomy minimizes the adverse effects of mortise distortion and enhances osteotomy site stability by the presence of an intact fibula.

A combined fibular osteotomy in medial opening-wedge supramalleolar osteotomy might affect the biomechanics of the tibiotalar and talofibular joints. Angular or rotational deformity of the distal fibula plays an important role in determining the contact areas and pressure distribution at the tibiotalar joint. Also, the effect of the fibula on the biomechanics of the tibiotalar joint is more marked with valgus deformity than with varus (6). The load can be transmitted by way of the talofibular joint, and the fibula can take part in the load transfer, particularly in valgus deformities (5). Lateral subfibular pain can develop after medial opening-wedge supramalleolar osteotomy because of valgus angulation and lateral translation of the hindfoot (9).

Although combined fibular osteotomy in medial opening-wedge supramalleolar osteotomy can biomechanically affect the tibiotalar and talofibular joints, the indication of fibular osteotomy has not been clearly established. Furthermore, few data have been reported regarding the biomechanical effects of combined fibular osteotomy.

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The purpose of the present study was to investigate the effect of combined fibular osteotomy on the pressure of the tibiotalar and talofibular joints in a cadaveric medial opening-wedge supramalleolar osteotomy model. We hypothesized that the talofibular joint pressure would increase after medial opening-wedge supramalleolar osteotomy without fibular osteotomy and that combined fibular osteotomy would reduce the increase in talofibular joint pressure.

Materials and Methods

Specimen Preparation and Testing Setup

Ten fresh-frozen, above-the-knee amputation specimens were obtained from 4 male donors and 1 female donor, with a mean age of 72 (range 56 to 85) years. Bony malalignment was excluded radiologically, and a normal range of motion in the ankle joint was verified in all specimens. Before the experiment, all the specimens were thawed at room temperature for ≥24 hours. The knee joints were disarticulated, preserving the intact tibiofibular joint. The skin, subcutaneous tissue, and muscles of the proximal tibiofibular joint and ankle joint were removed with preservation of the interosseous membranes and ligaments. The tibial plateau was transected, and the customized plate with a stem was inserted into the tibia after reaming the intramedullary canal. Additionally, two 6.5-mm Asnis III cannulated screws (Stryker, Mahwah, NJ) were inserted through the 2 holes on both sides of the stem. The specimen fixed to the plate was attached to a loading machine (FMS-2500-L2P force measurement system; LS Starrett Co., Athol, MA) using a ball-socket jig, which allows free axial rotation and angulation of the tibia under axial load (Fig. 1). The point of the load axis on the foot plate was marked as the point of intersection of vertical and horizontal lines. To match the talar dome center to the load axis, the talar dome center was positioned to coincide with both vertical and horizontal lines on the foot plate. The heel was buttressed by a lateral block to prevent the heel from sliding laterally, and the forefoot was stabilized with a strap.

The K-Scan 4000 system (Tekscan, South Boston, MA) was used to measure the pressure and force in the tibiotalar and talofibular joints. It consists of scanning electronics, software, and flexible thin-film (0.10-mm) sensors. The sensor has 2 identical, independent sensing arrays. Each sensing array is composed of printed circuits with grids of load-sensing regions. A “sensel” refers to each load-sensing region within the grid. Each sensing array has a total 920.7-mm^2 matrix area (27.9 mm × 33.0 mm), 572 sensels, and a density of 62.0 sensels/cm^2. Anterior and posterior ankle arthrotomies were performed to insert 1 sensor into the tibiotalar joint. The anterior and posterior talofibular ligaments were divided to insert the other sensor into the talofibular joint, and they were repaired with nylon 3-0 sutures after inserting the sensor. To avoid the sensors breaking away from the joints, the edges of the sensors were sutured to the surrounding periosteum and capsular tissues of the 2 joints anteriorly and posteriorly with Vicryl 2-0 suture.

A maximal load of 700 N was applied to simulate a single-leg stance with mean body weight (13). After 15 preconditioning cycles with a 700-N load, the static axial load was increased continuously from a 50 N preload to 700 N. The maximum load was maintained for 2 seconds, and peak pressures were captured at 50 Hz. The pressure magnitude and distribution, contact area, and force transmitted were measured using K-Scan 4000 software (Tekscan).

Osteotomy Procedures

For the medial opening-wedge supramalleolar osteotomy, the osteotomy plane was initiated 4 to 5 cm proximal to the tip of the medial malleolus and directed obliquely toward the syndesmosis, preserving the lateral cortex of the tibia (9,11,13). To create 3 different heights of the osteotomy gap, the osteotomy was stabilized using the H-plate (Arthrex, Naples, FL), which has 3 different block heights (6, 8, and 10 mm) after medial opening of the osteotomy. To prevent displacement of the osteotomy gap during the experimental axial load, a unilateral external fixator was also applied to the medial aspect of distal tibia. After measuring the joint contact pressures under 3 different tibial osteotomy conditions (6-, 8-, and 10-mm osteotomy gaps), a fibular osteotomy was performed in an inferomedial direction at the same level as that of the tibial osteotomy (9,14). After bending a one-third tubular plate to fit the valgus angulation of the fibular osteotomy site, which was determined by the height of the osteotomy gap, the plate was fixed with screws. Therefore, 7 different conditions were created in each specimen according to the combined fibular osteotomy and tibial osteotomy gap size as follows:

1. Intact specimen (before osteotomy)
2. Tibial osteotomy gap of 6 mm
3. Tibial osteotomy gap of 8 mm
4. Tibial osteotomy gap of 10 mm
5. Tibial osteotomy gap of 6 mm with fibular osteotomy
6. Tibial osteotomy gap of 8 mm with fibular osteotomy
7. Tibial osteotomy gap of 10 mm with fibular osteotomy

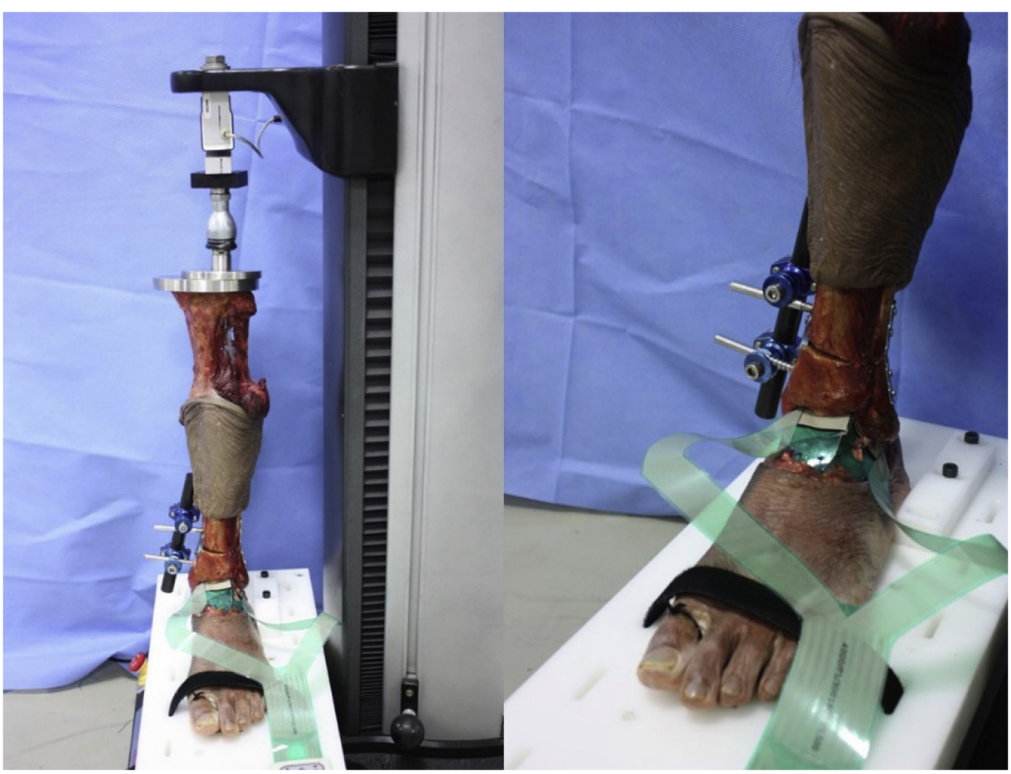

Fig. 1. Experimental setup. The specimen was fixed with the customized plate attached to the loading machine. Two identical, independent Tekscan pressure sensors were placed in the tibiotalar and talofibular joints, respectively.