Kinematic and Pedobarograph Evaluation Following Adolescent Triple Arthrodesis

Kirsten Tulchin, MS, Lori Karol, MD, and Carl St Remy, MD
Texas Scottish Rite Hospital for Children, Dallas, TX

Introduction: Triple arthrodesis consists of fusions of the subtalar, talonavicular, and calcaneocubiod joints. Long term gait results of triple arthrodesis have been reported previously, notably decreased sagittal ankle motion. No studies were found that examined motion of the hindfoot and forefoot using a more detailed foot and ankle model. The aim of this study was to evaluate the gait and pressure distribution of patients who had undergone triple arthrodesis for clubfoot or tarsal coalition. It was hypothesized that there would be decreased hindfoot motion imposed by the triple arthrodesis with increased compensatory forefoot motion.

Statement of Clinical Significance: Global decreases in forefoot and hindfoot motion may lead to accelerated ankle degenerative arthritis**.**

Methodology: Nine subjects (six males and three females) who had undergone triple arthrodesis returned for gait evaluation. The average age at examination was 25.1 ± 1.9 yrs (range 19.1 to 32.0). Five subjects had undergone unilateral triple arthrodesis for clubfoot. Four subjects underwent triple arthrodesis for tarsal coalition, three unilateral and one bilateral. The average age at surgery was 15.9 ± 1.9 yrs (range 12.8 to 19.1). The average post-operative follow-up time was 9.2 ± 5.5 yrs (range 2.5 to 15.9).

Fig 1: Foot marker set.

Patients were instrumented with a modified Helen Hayes marker set for lower extremity kinematics. Foot and ankle kinematics were obtained using the foot and ankle model, consisting of tibia and hallux triads and markers placed on the medial, lateral and posterior calcaneus, the heads of the first and fifth metatarsals and the base of the fifth metatarsal. (Figure 1) Kinematic data were collected at 120 Hz using a VICON 512 system (Oxford Metrics). Lower extremity data were processed with Vicon Clinical Manager (VCM). A custom model written using BodyBuilder for Biomechanics software was used to process foot and ankle kinematics. Simultaneous pedobarograph data were obtained with a EMED-ST plate with a resolution of 4 sensors/cm^2 (Novel, Inc.) using a three step method. The foot was broken into sections using the 'prc' automask within the Novel software. Kinematic and pedobarographic data were also collected for ten healthy individuals using the same testing protocol. Standing lateral and AP radiographs of the triple arthrodesis feet were also examined. Differences between means for the triple arthrodesis and control groups were tested using independent T-tests ($p<0.05$).

Results: Review of the radiographs revealed two patients with nonunion of the talonavicular joint. No evidence of degenerative arthritis of the remaining foot joints was seen.

Walking speed in the arthrodesis group was 83% of normal ($p<0.05$). No significant differences were seen in the pelvis or hip kinematics between the arthrodesis group and controls. Kinematic and pedobarograph results are shown in Table 1. Knee flexion curves showed slight hyperextension during midstance for the arthrodesis group compared to normal ($p<0.05$). Lower extremity ankle motion (as defined by VCM) showed decreased plantarflexion at toe-off and decreased sagittal ankle range of motion in the arthrodesis group compared to controls ($p<0.05$). The new model's foot and ankle analysis indicated decreased hindfoot range of motion (defined as motion between the tibia and calcaneus) in both the sagittal and coronal planes in the arthrodesis group ($p<0.05$). There were no correlations between increased range of motion of the forefoot (defined as motion between the calcaneus and the metatarsals) and decreased hindfoot motion in the sagittal ($r^2=0.1183$) or coronal ($r^2=0.1315$) planes in the arthrodesis group.

Table 1: Kinematic and pedobarographic measures of the triple arthrodesis group compared to normal. (mean ± standard deviation; * statistical significance from control group ($p<0.05$))

	Triple Arthrodesis Group (n=10 feet)	Control Group (n=10 feet)
Minimum knee flexion midstance (°)	-3.0 ± 3.5 *	2.1 ± 3.2
Maximum plantarflexion at toe-off (°)	5.7 ± 6.7 *	20.6 ± 6.0
Sagittal VCM Ankle ROM (°)	21.3 ± 3.4 *	31.6 ± 5.3
Sagittal Hindfoot (tib-calc) ROM (°)	18.3 ± 3.6 *	24.3 ± 5.4
Sagittal Forefoot (calc-meta) ROM (°)	13.8 ± 4.2 *	18.8 ± 3.6
Coronal Hindfoot (tib-calc) ROM(°)	6.2 ± 2.5 *	10.5 ± 2.5
Coronal Forefoot (calc-meta) ROM (°)	11.4 ± 3.8	12.0 ± 2.8
Medial Midfoot Contact Time (%ROP)	65.0 ± 13.4 *	39.0 ± 16.5
Medial Midfoot Contact Area (cm^2)	17.5 ± 8.7 *	4.1 ± 3.2
Medial Midfoot Peak Pressure (N/cm^2)	19.9 ± 6.0*	8.0 ± 2.4

Pedobarograph results revealed an increase in peak pressure, contact area and contact time in the medial midfoot mask of the triple arthrodesis group as compared to the control group.

Discussion: The slight increase in knee hyperextension during midstance, similar to that which was reported by Beisscher et al., is compensatory for decreased ankle motion. Subtalar fusion greatly limits the coronal plane motion of the tibial to calcaneal segment, as expected due to lack of talocalcaneal motion. The remaining coronal hindfoot motion is due to both a small amount of motion at the ankle and skin motion from markers. It was hypothesized that there would be increased forefoot motion. Sagittal plane forefoot motion however was decreased due to talonavicular and calcanealcubiod fusions. The forefoot does not move excessively to compensate for hindfoot stiffness, and furthermore, the ankle is limited in its motion as well. This may lead to degenerative changes at these joints in long-term follow-up.

References: Beischer, et al, Foot and Ankle International, 20(9):545-53, 1999**.**
Southwell and Sherman, Foot Ankle, 2:15-24, 1981.