THE ASSESSMENT OF FOOT FUNCTION AFTER ANKLE ARTHRODESIS

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Introduction
Arthrodesis is the surgical procedure in which joints are removed, adjacent bones repositioned, and fusion of the bones attempted. While the specific indications have expanded through the years, the general principles, (1) the correction of deformity, (2) the prevention of instability, and (3) the alleviation of pain, remain. In spite of its popularity, there are disadvantages to arthrodesis, including prolonged immobilization, a high pseudoarthrosis rate, and altered stresses on the neighboring joints of ankle. It is important to measure the limitation of motion of each joint after arthrodesis in order to understand its clinical implication. The purpose of this study was to identify the kinematic behavior and plantar pressure distribution of the foot after ankle arthrodesis during level walking with shoes. Also, the compensation mechanism after ankle arthrodesis in affected side and unaffected side was investigated.

Methods
Eight patients (mean age 51.6 yrs, mean height 162.0 cm and mean weight 64.0 kg) with single ankle arthrodesis performed due to trauma, degenerative osteoarthritis or rheumatic arthritis, were recruited for this study. Ten normal volunteers (mean age 24.7 yrs, mean height 164.0 cm, and mean weight 58.0 kg) without a history of congenital or traumatic deformity were selected to serve as control group.

A three-segment rigid body model was utilized to describe the motion of the foot and ankle. The segments consisted of the tibial/fibular, hindfoot/midfoot, and forefoot. A six-camera Expert Vision® HIRES System (Motion Analysis Corporation Santa Rosa, CA) was used to collect the three-dimensional trajectory data of markers placed on the subject at a sampling frequency of 60Hz while the subject is in action. Bony landmark set, marker triad set and four sizes shoes of the same trade-mark and pattern were used in the experiment. Two Kistler force plates (Type 9281B. Kistler Instrument Corp. Winterthur, Switzerland) was used to collect the three-dimensional force data. And, the EMED Pedar (Norvel Gmbh) system was used to collect pressure data from the EMED insole.

We set up the motion system and the foot pressure measurement system first, and took subjects’ history and measure their anthropometric data. Before testing, subjects were asked to practice walking many times with markers that were attached inside the subjects’ shoes. We collected static motion and foot pressure data in one second three times and dynamic data in five seconds ten times. There were one trial of static data and three trials of data that be chosen from those original data to analyze. Mann-Whitney test was used to compare the parameters of patient group with those of control groups. Kruskal-Wallis test is used to compare three groups: control group, affected side of patient group and unaffected side of patient group. Wilcoxon test is used to compare the parameters in the same group. Differences were considered significant when the P value was less than 0.05.

Results and Discussion
The results, in the affected side of patients, showed that the range of motion in three planes for forefoot increased to compensate the lacking range of motion in sagittal plane for rearfoot (Table 1). During the gait cycle, especially in stance phase, the forefoot in the affected side of patients demonstrated the dorsiflexion, valgus and external rotation, and that meant the forefoot excessively pronated in stance phase. The excessive pronation of forefoot could stretch the soft tissue between rearfoot and forefoot, especially the plantar fascia. According to Hicks, the plantar fascia is responsible for 60% of the stress applied to the foot during footflat. Therefore, the excessive pronation of the forefoot might result in plantar fasciitis (Donatelli, 1995).

The ground reaction force (Figure 1) for the affected side showed larger lateral shear force than the
unaffected side and those of the normal subject. The alteration in force vector may be explained by the pronated gait of these patients, who had excessive pronation for forefoot in stance phase. The reduction of peak progression force in sagittal plane and the obliteration of twin peak force in vertical ground reaction forces represent a decrease in the ability of force absorption and progression in the affected side of patient decrease.

The pressure and force of the affected side in two midfoot areas were greater than the others, and that may be explained by the pronated gait of these patients. In the forefoot and toe areas, the pressure and forces of patients were generally smaller than the others, which mean the lacking progression phenomenon in those patients. In the terminal stance, the smaller force-time integral (FTI) in the forefoot areas provided smaller ability of forward progression (Figure 2). Therefore the affected side lacked the ability of forward progression. In contrast, the greater FTI and pressure-time integral (PTI) of two rearfoot areas were found in the unaffected side of patients. Excessive pressure and force, and increased time in pressure or force are important factors related with foot injuries. Therefore the FTI and PTI are very important indexes considering with foot injuries.

The patients after ankle arthrodesis tend to use algetic gait pattern in our study. They walk slowly and avoid bearing weight on the affected side. Those alternations increase loading on the unaffected side of patients. The results show increased pressure, pressure-time integral and lateral shearing force on the unaffected side. Those increased loading maybe factors to cause injuries for the unaffected side of patients’ lower extremity. On the other hand, in order to compensate for the losing function of the rigid rearfoot, the forefoot of the affected side tends toward excessive pronation during stance phase. We also find the excessive range of motion in forefoot and increase lateral shearing force in the affected side of patients in our study. Those compensation mechanisms play important roles to induce foot injuries in walking for a long time.

References
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Table 1: The range of motion during gait cycle

<table>
<thead>
<tr>
<th>Range of Motion (°)</th>
<th>Patient group</th>
<th>Control group</th>
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<tr>
<td></td>
<td>Affected</td>
<td>Unaffected</td>
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</table>
| Rearfoot
| Dorsi/Plantar               | 11.6±2.3      | 19.7±3.6      | 19.2±2.3      |
|                             | **++          | **            | ++            |
| Inversion/Eversion
| Int./Ext. Rotation          | 12.0±3.7      | 9.8±2.0       | 10.1±2.9      |
| Forefoot
| Dorsi/Plantar               | 19.9±4.3      | 11.4±1.8      | 10.5±2.9      |
|                             | **++          | **            | ++            |
| Valgus/Varus
| Abduct/Adduct               | 13.6±3.5      | 11.6±2.1      | 10.9±2.1      |
|                             | 14.4±3.1      | 8.9±1.5       | 9.6±2.1       |

• Values were shown as mean ± 1 standard deviation; *,+: P<0.05, **,++P<0.01
Figure 1: Ground reaction force

Figure 2: force-time integral in 10 masks in stance phase