Accurate Measurement of Ankle Range of Motion after Total Ankle Arthroplasty

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There is no standardized method reported in the literature to measure ROM of the ankle after a total ankle arthroplasty, which limits the possibility to compare results from the various ankle designs. It seems that most of the measurements are a combination of ankle and midfoot motion, not the tibiotalar joint. A protocol was developed to accurately measure the true tibiotalar and midfoot motion before and after an ankle replacement. Lateral radiographs were taken of the ankle with the patient in a weightbearing position, and measurements were done along fixed landmarks. In this study, the tibiotalar, midfoot, and combined ROM were measured preoperative and 1 year postoperative in a standardized, reproducible fashion. The preoperative tibiotalar ROM was 18.5° and combined ankle and midfoot motion 25.1°. The true tibiotalar motion after an Agility total ankle arthroplasty was 23.4°, and the combined ankle and midfoot motion was 31.3°. The average improvement in ROM in the tibiotalar joint was approximately 5°, and combined ROM was 6.1°. Preoperative ROM proved to be the main factor determining the eventual postoperative ROM. It is possible to accurately measure the true ankle and the midfoot motion and those measurements should be used when reporting on the results of ankle replacements. Total ankle arthroplasty resulted in a statistically significant, but clinically less than expected, increase in ROM.

One such area is the ROM of the ankle after a replacement. There should be caution not to overestimate the ROM achieved by total ankle arthroplasty.

There is no standardized method reported in the literature to measure ROM. It seems that most of the measurements actually are a combination of ankle and midfoot motion, and not only the tibiotalar joint.1,2,7 It is thought to be important to quantify the true tibiotalar motion obtained with a total ankle arthroplasty in a reproducible manner. At this stage, there is no reference correlating ROM with outcome. With a standardized method of measuring ROM it might be possible to determine whether there is such a correlation.

A normal ankle moves from approximately 20° dorsiflexion, to 50° plantar flexion. A range of 24° to 30° combined motion (dorsiflexion and plantar flexion) is needed for normal walking, 37° is needed for ascending stairs, and 55° is needed for descending stairs.4,5

There are numerous reports on ankle arthroplasty in the literature.1–3,6,7 Few mention the preoperative and/or postoperative ROM. Some mentioned the ROM, but do not mention how the measurement was done.1,3

Kitaoka and Patzer2 measured the ROM of the foot relative to the leg in the sagittal plane with a goniometer. Before the arthroplasty, the mean dorsiflexion was 4° (range, 20° plantar flexion–25° dorsiflexion) and the mean plantar flexion was 22° (range, 0°–50°).

Postoperatively, the mean dorsiflexion of the 46 ankles that were examined clinically was 5° (range, 15° plantar flexion–20° dorsiflexion) and the mean plantar flexion was 19° (range, 0°–50°).7

Pyevich et al6 measured the ROM of the tibiotalar joint on radiographs taken with the ankle in maximum plantar flexion and dorsiflexion radiographs in 56 patients. The average ROM was 36° (range, 10°–64°). They did not measure the midfoot ROM.

The purpose of this study was twofold: to determine the true ROM of the tibiotalar joint after an Agility total ankle arthroplasty, and to present a reproducible way to accurately measure ankle and midfoot motion.
MATERIALS AND METHODS

All the patients who had a primary Agility total ankle replacement (DePuy, Warsaw, IN) at our institution were included in a prospective and ongoing study to determine the outcome of the ankle replacements. As part of the study, perioperative and postoperative data were collected.

The appropriate IRB approval from our institution, and written informed consent from the patient was obtained.

Inclusion and exclusion criteria included: all ankle replacements since 1999 in patients with at least 1-year followup; a complete set of radiographs; and no secondary procedures during the first year.

The radiographs included AP and lateral radiographs of the foot and ankle taken with the patient weightbearing and a lateral radiograph taken with the ankle in maximum plantar flexion and dorsiflexion.

The same sets of radiographs were taken preoperatively, 6 months postoperatively, and on a yearly basis thereafter.

In an attempt to standardize the radiographs, a rectangular plate was placed on the standing surface for radiographs taken with the patient weightbearing. For the AP view, the patient stands with the medial border of his or her foot along the edge of the plate (Fig 1).

The radiograph in the position of maximum dorsiflexion was taken in a weightbearing position with the foot on the same outline. The patient flexed the knee until the foot was in maximum dorsiflexion.

The radiographic view in maximum plantar flexion view was taken with the patient nonweightbearing and with the ankle in maximum active plantar flexion. All the radiographs were taken from a 1-m distance.

On the radiographs taken before surgery, Line A was drawn from the posterior to anterior lip of the distal tibia. On the lateral view taken with the patient standing with the ankle in neutral, Line B was drawn along the inferior aspect of the talus at the subtalar joint surface and Line C was drawn along the dorsal long axis of the first metatarsal. With the foot in maximum plantar flexion and dorsiflexion, the same lines were drawn and measurements were done with the tibial plafond as the reference (Fig 2).

On the radiographs taken postoperatively, the lines actually were easier and more reproducible to measure because of the keel of the Agility components. The stable line was Line A along the superior surface of the tibial keel (fin). This did not only allow for measurement of ROM, but also the orientation of the component in relation to the long axis of the tibia. The ideal position of the keel is perpendicular to the long axis of the tibia, but this was not always achieved.

The talar line, B, was drawn along the undersurface of the talar keel on all three lateral radiographs (neutral, maximum plantar flexion, maximum dorsiflexion). The first metatarsal line, C, was the same as in the preoperative radiographs (Fig 3). One observer did all the radiographic measurements at the time the radiographs were done.

Statistical Analysis

The unpaired t test was used for the analysis. A two-tailed p value was obtained, with a value of > 0.05 set as not significant.

RESULTS

There were 61 ankle replacements in patients with at least 1-year followup. Four were excluded because of secondary procedures done in the first year and seven were excluded because of inadequate radiographs. This left 50 patients with 50 ankle replacements in the study. The mean age of the patients was 59.4 years (range, 31–83 years). The average weight was 190 lb. (range, 111–260 lb). There were 33 men and 17 women. There were 29 right and 21 left ankle replacements. As mentioned before, all patients received an Agility total ankle arthroplasty.

The preoperative tibiotalar ROM was much less than the normal.2,3 Dorsiflexion was 2.1° (range, −2° to 10°). The mean ankle plantar flexion was 16.4° (range, 0.0° to 34.0°), with a combined true tibiotalar ROM of 18.5° (range, 3.0° to 44.0°) (Table 1).

At 1-year followup, there was a limited, but significant (p = 0.0037), improvement in the tibiotalar ROM (Table
1. The mean true ankle (tibiotalar) dorsiflexion was 4.2° (range, −1.0°–15.0°). The mean true ankle plantar flexion was 19.2° (range, 0.0°–42.0°). The total ankle ROM was 23.4° (range, 4.0°–57.0°).

The midfoot contributed approximately 1/3 of the total ROM (Table 1). The mean midfoot dorsiflexion motion at 1 year postoperative was 0.9° (range, 0.0°–3.0°) and plantar flexion was 7.0° (range, 0.0°–14.0°) for a combined 7.9° (range, 0.0°–17.0°) of motion through the midfoot.

The combined ankle and foot ROM mimicked what is reported as normal ankle ROM in the literature.1,3 The mean combined motion of the ankle and midfoot dorsiflexion postoperatively was 5.0° (range, 0.0°–18.0°) and plantar flexion was 26.3° (range, 6.0°–57.0°), for a total combined ROM of 31.3° (range 7.0°–74.0°). The increase in ROM was significant (p < 0.0008) (Table 1).

The posttraumatic group then was compared with the group with primary degenerative changes to see whether there is a predictable and significant difference in ROM. For the purpose of this study, posttraumatic was classified as having had at least one previous surgery for fracture treatment on that ankle.

From this differentiation, one can see that the primary group had a significantly better ROM than the posttraumatic group. There was a 6.7° (24%) better (p = 0.0095) tibiotalar ROM in the primary versus the posttraumatic group at 1 year (Table 2).

There was a 3.3° (15%) improvement (p = 0.0975) in tibiotalar motion at 1 year postoperative compared with the preoperative measurements in the posttraumatic group. This was not significant. There was a 3.7° (13%) improvement in the primary degenerative joint disease group (p = 0.2010).

**DISCUSSION**

There is neither a standardized method to measure ankle ROM after a total ankle arthroplasty, nor a differentiation between tibiotalar versus tibiotalar and foot combined in the literature.

With the proliferation of new ankle replacement designs, it is important to report accurate and reproducible...
data on the results of the various designs. That will be the only way we can adequately compare results. It is possible to accurately measure the true ankle and the midfoot motion and that probably should be used when reporting on the results of ankle replacements.

The study does have shortcomings. One observer did the radiographic measurements in all cases. There was no attempt to assess intraobserver or interobserver variations or reliability.

The preoperative and postoperative measurements were not done along the same landmarks. The measurement most likely to have intraobserver and interobserver variations is the measurement along the inferior aspect of the talus. This is an arbitrary landmark, but was thought to be the best in the situation.

The postoperative measurements are easier and predictable. The measurements along the keels allow for a true measurement of the ROM, even if the components were not implanted perpendicular to the long axis of the tibia. The measurements along the keels of the talus and tibial components are unique to the Agility ankle. There will have to be an agreement on which fixed landmarks the measurements will be done in other designs.

It is questionable whether idiopathic degenerative ankle joint disease really exists. It was thought that the majority of the disease in the idiopathic group resulted from long-standing ankle instability secondary to multiple lateral ankle ligament sprains. For this reason, the posttraumatic group consisted of patients who had at least one surgery to treat a fracture.

This study shows that the true tibiotalar motion after an Agility total ankle arthroplasty is approximately 23.4°. This is less than the 36° reported by Pyevich et al. That is enough to allow for a normal gait during walking. It might, however, still cause some abnormalities with ascending and descending stairs. Pyevich et al did not report on midfoot or combined motion.

An important issue is whether the ankle motion obtained with an ankle replacement is enough to protect the midtarsal and subtalar joints. At this early stage, it seems to be enough, but long-term followup will be necessary to determine the impact of ankle mobility on protecting the other joints.

Preoperative ROM proved to be the main factor determining the eventual postoperative ROM. There obviously will be exceptions, but on average the improvement in ROM in the tibiotalar joint only was approximately 5°. This is an important message to relay to the patients. Most patients, however, perceive the improvement to be substantial. The fact that the motion after a replacement essentially is pain-free versus the painful preoperative ROM might play a significant role in this subjective improvement.

An attempt was made to determine whether there were any specific comorbidities or predisposing factors that could reliably predict the postoperative ROM. The only

### TABLE 1. The Preoperative and Postoperative ROM Measurements of the Ankle and Foot

<table>
<thead>
<tr>
<th>ROM</th>
<th>Preoperative (n = 50)</th>
<th>6 Months (range)</th>
<th>1 Year (range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ankle dorsiflexion</td>
<td>2.1 (−2 to 10)</td>
<td>3.7 (−2 to 15)</td>
<td>4.2 (−1 to 15)</td>
</tr>
<tr>
<td>Ankle plantar flexion</td>
<td>16.4 (0 to 34)</td>
<td>18.7 (0 to 36)</td>
<td>19.2 (0 to 42)</td>
</tr>
<tr>
<td>Tibiotalar ROM</td>
<td>18.5 (3 to 44)</td>
<td>22.3 (4 to 51)</td>
<td>23.4 (4 to 57)</td>
</tr>
<tr>
<td>Foot dorsiflexion</td>
<td>0.8 (0 to 2)</td>
<td>0.8 (0 to 2)</td>
<td>0.9 (0 to 3)</td>
</tr>
<tr>
<td>Foot plantar flexion</td>
<td>5.9 (0 to 14)</td>
<td>6.3 (0 to 13)</td>
<td>7.1 (0 to 14)</td>
</tr>
<tr>
<td>Foot ROM</td>
<td>6.6 (0 to 16)</td>
<td>7.0 (0 to 15)</td>
<td>7.9 (0 to 17)</td>
</tr>
<tr>
<td>Combined</td>
<td>25.1 (4 to 48)</td>
<td>29.3 (6 to 49)</td>
<td>31.3 (7 to 74)</td>
</tr>
</tbody>
</table>

### TABLE 2. ROM in a Posttraumatic Versus an Idiopathic Degenerative Joint Disease Group

<table>
<thead>
<tr>
<th>ROM</th>
<th>Posttraumatic (n-32)</th>
<th>Primary DJD (n-18)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Preoperative (range)</td>
<td>1 Year (range)</td>
</tr>
<tr>
<td>Tibiotalar joint: total</td>
<td>18.5 (0 to 35)</td>
<td>21.8 (4 to 35)</td>
</tr>
<tr>
<td>Foot total</td>
<td>7.0 (0 to 15)</td>
<td>7.0 (0 to 15)</td>
</tr>
<tr>
<td>Combined</td>
<td>25.4 (0 to 44)</td>
<td>28.8 (7 to 46)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>24.8 (8 to 44)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5.8 (0 to 12)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>30.7 (8 to 56)</td>
</tr>
</tbody>
</table>
consistent factor was a history of a severe pilon fracture with significant soft tissue injury and at least three previous surgeries, including an initial extensive open reduction and internal fixation. Three such patients were identified and no patient gained any motion over the preoperative measurements.

The most striking observation was that the overall improvement in tibiotalar ROM, even though statistically significant ($p = 0.0037$) only was $5^\circ$. Therefore it is important to realize that the main factor determining postoperative ROM is preoperative ROM.

The numbers were not large enough to make specific statistical conclusions, but a trend emerged. Patients with little motion preoperatively had a trend to a slight increase in ROM postoperatively. Patients with a good ROM preoperatively maintain or might lose some motion. If the patient begins with reasonable motion, approximately the same motion should be maintained.

Ankle replacement surgery does not increase ankle ROM dramatically, but with the reduction in pain, the patient seems to be able to use the ROM more effectively.

References