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Original Research

Sagittal Ankle and Midfoot Range of Motion Before and After Revision Total Ankle Replacement: A Retrospective Comparative Analysis

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ABSTRACT

The most common reason for a revision total ankle replacement procedure is a painful, stiff ankle even after the initial surgery. Limited and conflicting data are available regarding the change in sagittal foot and ankle range of motion after revision total ankle replacement surgery. We sought to determine whether revision total ankle replacements would reduce compensatory midfoot range of motion. In determining this, a novel radiographic measurement system with stable osseous landmarks is used. A retrospective medical record review of patients who had undergone revision total ankle replacement from January 2009 to June 2016 was performed. Thirty-three patients (33 ankles) underwent revision total ankle replacement surgery and met the inclusion criteria with a mean follow-up period of 28.39 ± 14.68 (range 2 to 59) months. Investigation of preoperative and postoperative weightbearing lateral radiographic images was performed to determine the global foot and ankle, isolated ankle, and isolated midfoot sagittal ranges of motion. Statistical analysis revealed a significant increase in ankle range of motion ($p = .046$) and a significant decrease in midfoot range of motion ($p < .001$) from preoperatively to postoperatively. The change in global foot and ankle range of motion was not significant ($p = .53$). For this patient population, the increased ankle range of motion effectively resulted in less compensatory midfoot range of motion.

More predictable outcomes with modern generation total ankle replacement (TAR) prostheses have led to renewed interest for their use in treating end-stage ankle arthritis (1–3). A resurgence of interest, coupled with refined indications and contraindications, has positioned TAR as a viable alternative to ankle arthrodesis (4,5). This has resulted in a sustained increase in the frequency of primary TAR implantation, which will ultimately necessitate an increase in revision surgery. This pattern has been demonstrated in the Norwegian Arthroplasty Register (available at: http://nrlweb.ihelse.net/Rapporter/Rapport2016.pdf). From 2000 to 2015, one third of all registered TARs performed were revisions. A common etiology reported for revision TAR is pain associated with stiffness (3,6–11). Despite the citation of pain associated with stiffness as a common cause for revision TAR surgery, scant available data exist regarding changes in sagittal range of motion (ROM) of the foot and ankle after revision TAR.

Kimberly, in 1936, was the first to suggest that the clinical results of ankle arthrodesis are affected by the preoperative stiffness of the midfoot and the ability for the midfoot to become more flexible over time (12). Multiple subsequent reports have demonstrated that preexisting adjacent midfoot degenerative joint disease is present in 80% to 100% of patients with ankle arthritis (13–16). It has also been suggested that preexisiting midfoot degenerative joint disease worsens in ~65% of patients after ankle arthrodesis (17–20). A mechanical rationale for this concept was offered by Suckel et al (21), who performed a dynamic, cadaveric analysis of midfoot intraarticular contact pressure during foot strike before and after ankle arthrodesis. They determined that before ankle arthrodesis, a continuous increase of load transmission was present in the midfoot; however, after ankle arthrodesis the midfoot load transmission increased significantly (21). In contrast, Ling et al (22) performed a systematic review of 24 reports involving 18 clinical, 5 biomechanical, and 1 gait analysis study, They found the prevalence of subtalar joint degenerative joint disease was 24% to 100%, with an incidence of midfoot degenerative joint disease

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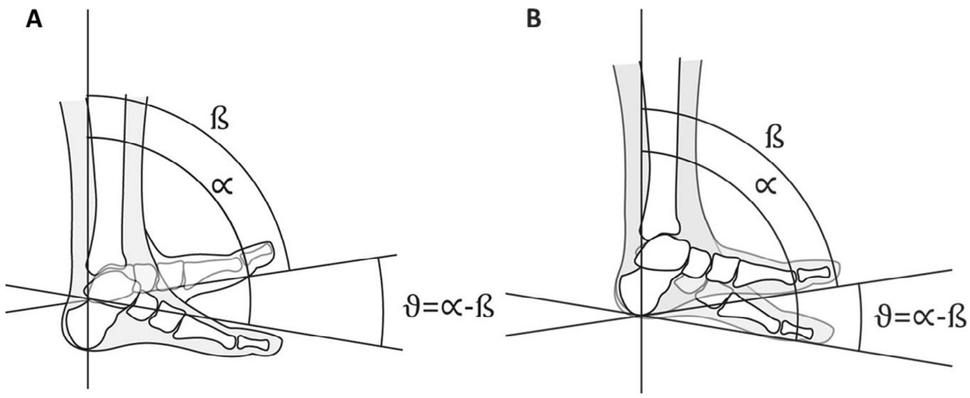

Fig. 1. *(A)* Calculation of ankle joint total sagittal range of motion *(ϑ)* by subtraction of isolated ankle dorsiflexion *(β)* from isolated ankle plantarflexion *(α)*. *(B)* Calculation of global sagittal range of motion *(ϑ)* by subtraction of global dorsiflexion *(β)* from global plantarflexion *(α)*.

of 18% to 77% after ankle arthrodesis (22). They concluded that no true consensus has been reached on whether ankle arthrodesis leads to adjacent midfoot/hindfoot degenerative joint disease and that no conclusive correlation exists between adjacent joint radiographic changes and patient symptoms (22).

In 1979, Jackson and Glasgow (23) sought to determine whether midfoot stiffness after successful, well-aligned ankle arthrodesis affected the patient's results. If this were proved, they believed TAR would be favored over ankle arthrodesis in the presence of preoperative midfoot stiffness. Investigation using a follow-up analysis of unilateral isolated ankle arthrodesis was performed comparing sagittal plane ROM with that of the contralateral side (23). After review of nonweightbearing lateral maximum dorsiflexion and plantarflexion radiographs, they concluded that a flexible midfoot was not an essential factor to attain an acceptable result after ankle arthrodesis (23). They stated that their experience demonstrated the best patient outcomes in those who had had "average" midfoot mobility postoperatively (23). In support of this concept, Braito et al (24) demonstrated radiographic worsening of midfoot and hindfoot degenerative joint disease in 81% of patients who had undergone TAR compared with 65% after ankle arthrodesis.

No true consensus has been reached on whether preoperative stiffness of the midfoot affects the outcomes of ankle surgery. Because of the limited and conflicting information available, we sought to determine whether revision of failed primary TAR would reduce compensatory midfoot ROM. This information would assist both surgeons and patients in shaping expectations of achievable ROM after revision TAR. Additionally, we hoped to elucidate the effects of renewed ankle sagittal ROM on midfoot sagittal ROM.

Patients and Methods

After approval of the project design and methods by our institutional review board, a review of prospectively collected data was performed at our tertiary referral center in the Midwestern United States to identify those patients who had undergone revision TAR from January 2009 to June 2016. Patients were considered for inclusion if they had undergone revision TAR, with no limitation on the prostheses used or etiology leading to revision. The exclusion criteria included a lack of appropriate preoperative and postoperative weightbearing lateral radiographic series with the ankle in maximal dorsiflexion, maximal plantarflexion, and neutral standing positioning and revision consisting of explantation of the failed primary TAR and conversion to arthrodesis. A manual review of the medical records was then conducted for each patient to collect the demographic and surgical information.

During the initial investigation, we identified flaws in the previous radiographic measurement methods used, including the use of osseous landmarks frequently altered during prosthesis placement or obscured by TAR prosthetic components. Therefore, we developed a novel measurement system to identify the radiographic changes in sagittal ROM in patients who have undergone primary and revision TAR. The required radiographs included preoperative and postoperative lateral weightbearing series with the ankle in maximal dorsiflexion, maximal plantarflexion, and neutral standing positioning. To obtain these images, the patient was placed in the normal angle and base of gait and then instructed to maximally dorsiflex and plantarflex the ankle while maintaining the sole of the foot in complete contact with the weightbearing surface. A standardized protocol was used by certified radiology technicians experienced with these radiographs.

Sagittal ankle and midfoot ROM was measured using the preoperative and longest postoperative follow-up lateral weightbearing maximum dorsiflexion and plantarflexion views (Fig. 1). Measurement of global plantarflexion and dorsiflexion motion was obtained using the angle between the plantar weightbearing surface and the posterior tibial diaphysis axis, because the posterior tibia is rarely obscured even with intramedullary TAR systems. Global ROM of the ankle was then calculated by subtracting the global dorsiflexion from the global plantarflexion (Fig. 1B). The amount of motion attributable to the ankle joint was determined in plantarflexion and dorsiflexion using the angle between the posterior tibial diaphysis axis and a line drawn along the inferior talus from the most posterior aspect of the posterior subtalar joint facet to the inferior talar head as described by van der Plaat et al (25). This line along the inferior talus is easily visualized even when degenerative changes are present. Total ankle motion was calculated by subtraction of the ankle dorsiflexion from the ankle plantarflexion (Fig. 1A). Sagittal ROM attributed to the midfoot was then calculated through subtraction of the total ankle ROM from the global ROM. All measurements were performed electronically using the Synapse® picture archiving and communication system (FujiFilm Medical Systems USA, Inc., Stamford, CT) independently by 2 of us (P.J.H., B.A.F.) with complete consensus measurements recorded.

The preoperative and postoperative radiographic measurements were analyzed using a nonparametric Wilcoxon signed rank test, with statistical significance set at $p < .05$.

Results

From January 2009 to June 2016, the senior author (T.S.R.) performed 33 revision TARs (22 left; 11 right) on 33 patients (20 males, 13 females) who met the criteria for inclusion. The mean patient age at the index primary TAR surgery was 57 ± 12 (range 32 to 87) years. The mean patient age at revision TAR surgery was 65 ± 11 (range 46 to 90) years. The mean follow-up period was 28.39 ± 14.68 (range 2 to 59) months (Table 1).

The included patients had had 1 of 3 primary TAR prostheses implanted: 29 (87.88%) received the Agility™ TAR (DePuy Synthes Joint Reconstruction, Warsaw, IN); 2 (6.06%), the INBONE® I TAR (Wright Medical Technologies, Inc., Arlington, TN); and 2 (6.06%), the Scandinavian Total Ankle Replacement Prosthesis (STAR™; Stryker Orthopeadics, Inc., Mahwah, NJ). These were revised to 1 of 3 systems: 18 (54.55%) were revised to the Agility™ TAR (DePuy Synthes Joint Reconstruction) with custom-stemmed, revision or LP talar components; 8 (24.24%) to an INBONE® II TAR (Wright Medical Technologies, Inc.); and 7 (21.21%) to a Salto Talaris® XT revision ankle prosthesis system (Integra Life Sciences, Plainsboro, NJ; Table 2). Agility™ to Agility™ revisions accounted for 18 of 33 procedures (54.55%). Conversions of Agility™ to INBONE® II accounted for 6 of 33 procedures (18.18%).