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Dynamic Ultrasonography: A Cadaveric Model for Evaluating Aseptic Loosening of Total Ankle Arthroplasty

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ABSTRACT

Aseptic loosening is the primary method of failure in total ankle replacements. Currently, loosening is defined by morphologic changes in osseous architecture determined by plain radiography. The loss of bone noted at diagnosis presents difficulties in future ankle revisions. A method by which early aseptic loosening could be detected before bony deformation or reaction could lead to improved patient outcomes. A cadaveric fresh frozen ankle specimen (mid-tibia to include the foot) was used in the present study. An anterior approach to the ankle was performed. A total ankle prosthesis was implanted in the standard fashion (Salto Talaris, Tornier). The initial cuts were made for a size 1 ankle, and a size 1 ankle was implanted. Dynamic ultrasonography was used to evaluate the bone–implant interface. The prosthesis was removed, and sequential removal of bone was performed at the interface of the medial tibial tray until visible motion was seen with flexion and extension. The reimplanted prosthesis was then re-evaluated using dynamic ultrasonography and dynamic and static fluoroscopy. In the loose prosthesis model, dynamic ultrasonography was able to determine the motion at the bone–prosthesis interface. Dynamic ultrasonography might be a useful tool in the evaluation of early loosening in a total ankle arthroplasty model.

Aseptic loosening after total ankle arthroplasty is a common cause of postoperative pain, component failure, and eventual revision surgery (1). Evaluating the prosthesis position is an integral component of the postoperative management. Subtle changes are often difficult to evaluate with plain radiographs. Multiple static parameters have been described to assist in the determination of early failure. Complicated linear values have been developed to assist in radiographic evaluation; however, the use of these measurements is not always practical (2). Computed tomography (CT) has been used to evaluate postoperative lucencies, but it must be modified to decrease the metal artifact and is not an effective screening tool, given the cumulative radiation dose (3,4). The association between periprosthetic lucency and component failure has not been definitively established. Visual confirmation of motion at the bone–prosthesis interface would facilitate the diagnosis and early intervention and could possibly improve the outcomes after total ankle arthroplasty.

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The efficacy of dynamic ultrasonography in evaluating soft tissues and bony pathologic features in the foot and ankle is well established (5,6). Ultrasonography has primarily been used to evaluate the integrity of the lateral ligaments, luxation of the peroneal tendons, and irregularities in the metatarsal and cuneiform bones (7). The use of ultrasonography in evaluating total joint replacements has been limited. It has been suggested that ultrasound evaluation could be a screening tool for mild cases of polyethylene wear (8).

The purpose of the present study was to determine whether dynamic ultrasonography could detect loosening at the bone–prosthesis interface in total ankle arthroplasty.

Materials and Methods

A fresh frozen cadaveric leg specimen was used for the present study. Care was taken to ensure that no previous soft tissue injuries, bony injuries, or surgeries had occurred that would affect the ultrasound results. An anterior approach to the ankle was performed in the interval between the anterior tibialis tendon and the extensor digitorum longus. A Salto Talaris total ankle replacement prosthesis (Tornier, Amsterdam, The Netherlands) was implanted according to the manufacturer's technique guide. The ankle was visibly inspected to ensure that it was stable to stress evaluation with no gross motion seen in dorsiflexion, plantarflexion, inversion, or eversion. The anterior soft tissue envelope was closed with a running Prolene suture, and the joint was insufflated with normal saline.

All ultrasound scanning was performed with a 12-MHz linear transducer and a single ultrasound machine (IU 22, Philips Medical, Best, The Netherlands) with scan

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settings optimized for musculoskeletal ultrasonography. A board-certified musculoskeletal radiologist with 10 years' experience in musculoskeletal ultrasonography obtained all the measurements. The prosthesis–bone interface was evaluated in 6 different locations statically and dynamically while manipulating the ankle into different positions: superomedial (at the tibial–prosthesis interface), superolateral, anterosuperior, distal medial (talar component), distal lateral, and distal anterior. At the conclusion of that portion of the study, it was determined that the best acoustic window to evaluate the bone–prosthesis interval was located at the superomedial aspect of the joint because this allowed unobscured visualization of the lateral tibia to component articulation.

Once the dynamic evaluation and static measurements were complete, the incision was opened, and the prosthesis dynamized. This was performed by sequentially removing bone from the medial aspect of the tibial tray in 1-mm increments until such time as motion could be seen at the tibial–prosthesis interface. A calibrated linear ruler was used to measure the gap at 4 mm. The anterior soft tissue envelope was closed, and the joint was again insufflated with saline. Dynamic ultrasonography was then used to evaluate the lateral tibia–prosthesis interface during flexion and extension of the ankle. The images were saved in full extension and full flexion. Identical measurements were then taken using fluoroscopy.

Objective measures were made in full extension and full flexion with both ultrasonography and fluoroscopy. The fluoroscopic images required a pixel to millimeter conversion once the images were digitally uploaded. Images in full flexion and extension are shown in Figs. 1 and 2.

Results

The superomedial window was the optimal location for evaluating the tibial tray. Through this window, the bone–prosthesis interface could be measured at the lateral portion of the tibial tray. The superolateral window was shadowed by the fibula. The anterior window was not useful owing to the posterior slope of the prosthesis. The talar component could not be measured in the medial or lateral gutters, because the chamfer cuts prevented any overhang of the prosthesis or step-off from which to measure dynamic motion. Again, the slope of the talus did not allow measurement through the anterior window. The superomedial window was located at the bone–prosthesis interface just medial to the anterior tibialis tendon. The exact position of the superomedial window can vary with body habitus but will be readily apparent at the tibial–prosthesis interface.

In the static model, no motion artifact was visible using ultrasonography at the bone–prosthesis interval. Testing was done as the ankle was brought through full flexion and full extension. After the ankle was dynamized, a motion artifact was clearly seen. The measurements taken at full flexion and full extension were correlated with the fluoroscopic measurements.

In full extension, the fluoroscopic images demonstrated a bone–prosthesis gap of 4.4 mm. This increased to 5.4 mm in full flexion. This accounted for a difference of 1 mm pistoning seen clinically. Ultrasonography measured a gap of 2.44 mm in full extension and 3.01 mm in full flexion. This accounted for a difference of 0.57 mm pistoning.

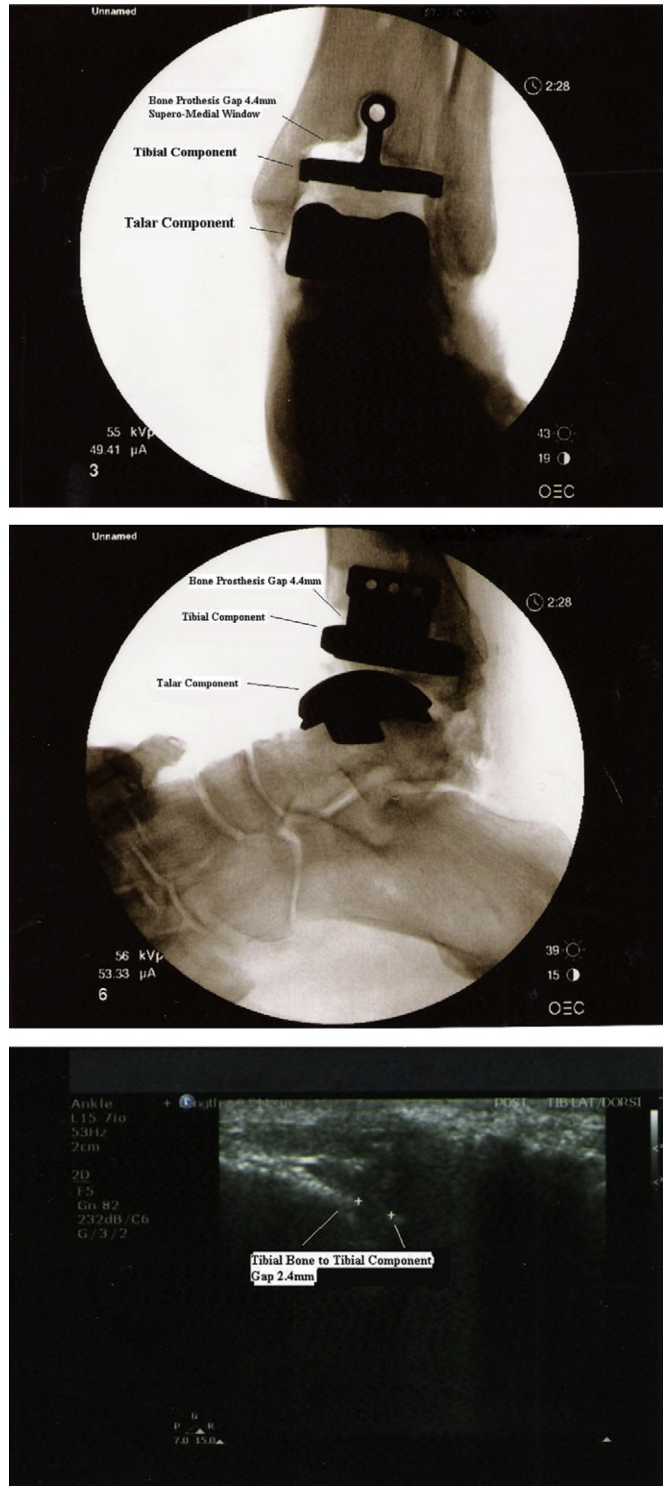

Fig. 1. Dorsiflexion view.

Discussion

Second-generation total ankle replacements have demonstrated promising short-term results. The 5-year survival rates have ranged from 77% to 93% (1). In a systematic data review, Haddad et al (1) found an overall revision rate of 7%, with loosening the most common indication for revision (28%).

To evaluate postoperative radiographs for evidence of loosening, Bestic et al (2) described a method for evaluating component migration or subsidence using a system of angular and linear measurements. Although the measurements compared the position of the prosthesis to the surrounding osseous structures, angular differences in the radiographic technique of the incident beam could alter the results. Angular changes of 5° are thought to represent subsidence or component migration (9). Although an angular malalignment of 5° would lead many surgeons to consider revision, it does not allow for detection of loosening at a stage at which nonoperative interventions could occur. Lucency adjacent to the prosthesis has been associated with loosening. Although some lucency could be related to the surgical technique, lucencies greater than 2 mm have been associated with hardware migration (10). Although lucency is thought to be the result of motion, the accuracy or positive predictive value of this radiologic measurement has not been established.