Evaluation of Total Ankle Arthroplasty Design Considered Motion Characteristics of Ankle Joint for Responding to Sudden Tilting Perturbation

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Category: Ankle, Ankle Arthritis

Keywords: Total Ankle Arthroplasty, Tilting Perturbation, Ankle Joint Motion Characteristics, artificial prosthesis

Introduction/Purpose: Total Ankle Arthroplasty (TAA) has been introduced as one of treatment methods for the arthritis of the ankle joint. Traditional TAAs have been generally designed considering the anatomical geometry and motion characteristics of the ankle joint for responding to general activities of daily living (ADLs). However, traditional TAA designs do not well consider the anatomical geometry and motion characteristics for responding to a sudden perturbation although the ankle joint contributes partially to human balance to prevent falling induced by a sudden perturbation. The aims of the current study were therefore to identify the anatomical geometry and motion characteristics of the ankle joint during sudden tilting perturbations, to reflect the motion characteristics in the design of TAA, and to evaluate the design.

Methods: Following Institutional Review Board approval (IRB No SJU-2015-002), seven healthy participants with no sign of musculoskeletal pathology (gender: 7 male, 25.5±1.7 years, height: 173.9±6.4 cm, weight: 71.3±6.5 kg) were tested to identify the motion characteristics of the ankle joint during sudden tilting perturbations. Eight sudden tilting perturbations were then implemented by the tilting perturbation simulator developed by our research group. The motion characteristics were measured by using a three-dimensional motion capture system with eight infrared cameras (T-10s, VICON Motion System Ltd., UK). The motion characteristics, particular in the range of motion (ROM) and motion trajectory, were reflected in the design of TAA. The evaluation of the design of TAA was conducted using finite element (FE) analysis in accordance with the international testing standard ASTM F2665, F1223 and F1814.

Results: Dorsi/plantar flexion, inversion/eversion and abduction/adduction were ranged from 11.2±1.5° to -9.3±3.5°, 7.0±4.0° to -7.8±4.9°, and 0.7±0.2° to -1.0±0.2°, respectively, for the sudden tilting perturbations. Dorsi/plantar flexion of TAA designed newly were 1.5 times larger than that measured from the experiment above, with no interference. Inversion/eversion and internal/external rotation of TAA designed newly were favorably compared to those measured from the experiment above. The motion trajectories were different a little compared to those measured from the experiment above. Maximum von mises stresses predicted from FE analysis with the international test conditions were not exceed a yielding strength of the material used for TAA designed newly and no dislocations among the TAA components were identified.

Conclusion: The results indicated that a realization of the natural ankle joint motion trajectory should be improved although TAA design suggested in the current study might well present ROMs for responding to sudden tilting perturbations and have a proper structural stability corresponded to the standard criterion recommended from the international testing standard. The TAA design will be, therefore, modified more considering advanced anatomical and biomechanical parameters, particular in the characteristics of the ankle joint motion trajectory, in our ongoing study. The current study may be, however, valuable to suggesting new TAA design for responding to a sudden perturbation to prevent falling.

Foot & Ankle Orthopaedics, 2(3)
DOI: 10.1177/2473014175000262
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