

IN-VIVO KINEMATICS OF THE THREE COMPONENTS OF A TOTAL ANKLE PROSTHESIS

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INTRODUCTION

A novel Total Ankle Replacement (TAR) design allows complete congruence at the three components throughout plantar-/dorsi- flexion (PIDo) arc due to the compatibility of the articulating surfaces with the retained ligaments [1]. This was achieved with a convex spherical tibial and an anticlastic talar component, the latter with a larger radius of curvature than that of the natural talus in the sagittal plane, unlike most of the current three-part designs. The design followed measurements on cadaver specimens in virtually unloaded conditions and predictions from mathematical models [1]. These suggested that the meniscal bearing would move forwards on both components during dorsiflexion and backwards during plantarflexion. Scope of the present study is to confirm these claims with accurate measurements of motion of the components on patients implanted with this TAR. Observations intra- and post- operatively were performed particularly to assess whether meniscal motion occurs and it is maintained at consecutive follow-ups.

METHODS

At operation, range of ankle motion was measured in 102 ankle before and immediately after implantation of the final components of the novel TAR design (BOX, Finsbury Orthopaedics, Leatherhead-Surrey, UK). This has a mobile bearing polyethylene insert instrumented with 3 tantalum beads in known positions.

In 31 of these patients, the range of postoperative motion in the sagittal plane of the metal and meniscal components was measured in couples of X-ray pictures, taken at maximum plantar- and dorsi-flexion at different follow-ups.

Three patients were also analyzed at 12, 18 and 24 month follow-up using a standard fluoroscope (CAT Medical System, Rome, IT) at max 10 Hz during stair ascending/descending and flexion against gravity. Tibial and talar component reference frames were defined onto relevant CAD models according to the three anatomical directions, that of the insert was defined by using the 3D coordinates of the tantalum beads. Position and orientation of the 3 components were obtained by an iterative 2D-to-3D matching procedure with a 0.5 mm/1.0° accuracy [2]. PIDo, inversion-eversion (InEv), internal-external (InEx) rotation, as well as antero-posterior (AP) translation of the meniscal bearing with respect to the tibia were expressed according to the standard convention for joint rotations.

RESULTS AND DISCUSSION

At the operating theatre, between pre- and post- operation, dorsi-flexion increased on average from -0.8° to 9.6°, plantarflexion from 15.6° to 25.4°. The meniscal bearing was observed to move exactly as predicted by the models, and in full conformity with the metal components throughout the

flexion arc. The range of postoperative motion from X-rays, 14° - 53°, was significantly correlated to the range of bearing movement on the tibial component, 2-11mm, measured radiologically, (Figure 1; $R^2 = 0.37$, $p < 0.0005$).

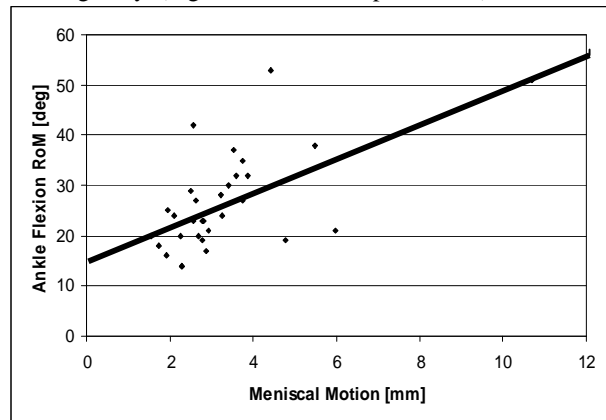


Figure 1: Correlation plot between range of ankle dorsi-plantarflexion and meniscal AP displacement.

With 3D fluoroscopy-based technique, at the last follow-up, for the 3 motor tasks, about 7°, 5° and 11°, PIDo were coupled with respectively 3°, 3° and 4° InEv and 4°, 4° and 3° InEx when averaged over the 3 patients. In flexion against gravity, this coupling was significant ($p < 0.05$). AP translation of the meniscal bearing was also significantly coupled with PIDo in all motor tasks ($p < 0.01$), mean range over the 3 follow-up being 2.0-2.1-2.4 mm in stair ascending, 2.7-2.5-1.9 mm in descending, 2.4-2.4-2.5 in flexion.

CONCLUSIONS

For the first time, motion of all three TAR components, was tracked in-vivo by using different procedures. Particularly, AP motion of the meniscal bearing was about 2-3 mm for each 10° flexion, consistently over the procedures and maintained over the follow-ups. These observations support the main features claimed for this novel TAR, and imply also the full congruence between the three components and restoration of ligament natural function. In the future, measurements on larger cohorts of patients integrated with the gait analyses [3] already in progress will provide even more synergic information about overall functional recover.

REFERENCES

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