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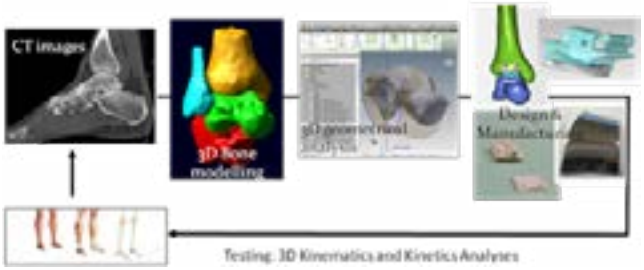
Personalized design and 3D printing for human total ankle prostheses: In-silico and in-vitro experimental evaluation

Belvedere C[1], Siegler S[2], Caravaggi P[1], Fortunato A[3], Durante S[1], Liverani E[3], Ensini A[1], Tomesani L[3] and **Leardini A[1]**
[1]Istituto Ortopedico Rizzoli, Italy
[2]Drexel University, USA
[3]Università di Bologna, Italy

Current total ankle prosthesis designs are based on cylindrical (CYL) or medially-oriented truncated-cone (TCM) geometries. A recent image-based morphological study demonstrated that natural ankle surfaces can be approximated by a laterally-oriented saddle-shaped skewed truncated-cone (SSCL). The aim of this study was to compare the three designs in terms of their efficacy in restoring natural ankle kinematics and flexibility. Ten cadaveric lower-limbs underwent a validated process for custom designing of these geometries, including medical imaging, 3D-modeling and printing of the three relevant implantable sets of customized articular surfaces for tibiotalar replacement. Mechanical tests under cyclic loading were performed on each specimen, before and after the implantation of each of the three sets. Torques in out-of-sagittal plane directions were applied in neutral position and at joint flexion extremes. Corresponding in-silico simulations were also performed to estimate ligament strain/stress. The performances of custom-made artificial surfaces were compared with that of the natural joint surfaces. SSCL surfaces replicated the physiological mechanical characteristics better than CYL and TCM, both at the ankle and subtalar joints, in all anatomical planes. In particular, in most of the specimens, SSCL was superior on a statistical basis compared to the other two surface approximations, especially for the responses in maximum dorsiflexion. In-silico evaluations confirmed more physiological ligament strain/stress patterns for SSCL surfaces. All analyzed implant sets were originally designed to match the specific morphology of each tested specimen according to the three designing approaches. This study therefore represents well a possible future process of patient-specific ankle prosthesis designing and manufacturing.



Biography

Belvedere C has completed his PhD from University of Bologna, Biomedical Engineering. He has published about 40 papers has been serving as an editorial board member in a number of reputed international journals.

belvedere@ior.it

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