AUTOMATICALLY DESIGNED PATIENT-SPECIFIC INSTRUMENTATION FOR TOTAL ANKLE REPLACEMENT: AN IN-VITRO STUDY

Michele Conconi (1), Nicola Sancisi (1), Alberto Leardini (2), Massimiliano Mosca (3), Silvio Caravelli (3), Claudio Belvedere (2)

1. Dept. of Industrial Engineering, University of Bologna, Italy; 2. Movement analysis Laboratory, IRCCS Istituto Ortopedico Rizzoli, Bologna, Italy; 3 II Clinical Department, IRCCS Istituto Ortopedico Rizzoli, Bologna, Italy

Introduction

Recent adoption of patient-specific instrumentation (PSI) in total ankle replacement (TAR) has enhanced positioning of the implant components, eliminating the need for complex external cutting jigs [1], with a significant decrease in operative time, reducing costs and risk for the patient [2]. We present an automatic procedure for the surgical pre-planning of TAR, also defining the cutting PSI for the tibia and talus. The accuracy of the proposed PSI is tested on one specimen.

Methods

The proposed procedure is based on the alignment of the BOX® Total Ankle Replacement – MatOrtho, but it is easily generalizable to different TAR. A pre-op CT scan (DICOM slicing 0.26mm) is acquired with neutral foot (Fig 1.A). To refer the implant, tibia and talus anatomical reference systems (ARS) are defined [3] and three points on the calcaneus, first, and fifth metatarsal bones are virtually palpated to identify the ground plane (Fig 1.B). If flexion angle in the pre-op scan is suboptimal for accurate surgical plan, flexion is adjusted using a patient specific ankle model reconstructing the individual joint motion based on articular morphology [4]. The implant is then aligned with the ground plane and ARS orientation. The surgeon can choose the implant size and between two axial alignments (Fig 1.C): the first based on the foot longitudinal axis, from the ankle center to the head of the second metatarsal; the second based on the mean orientation of the gutter planes. Once the prosthetic alignment has been confirmed, the bone models are virtually cut and the implant positioned (Fig. 1.D). PSI geometry is defined by intersecting a reference volume with patient's bone model and TAR cuts (Fig. 1.E).

To test the procedure, we planned TAR for a specimen. The PSI were 3D printed (Fig. 1.F) and used to perform the cuts (Fig 1.G). After surgery, a post-op CT scan was performed and the position and orientation errors of post-op cuts with respect to the planned ones were quantified by model-to-model registration.

Results

Figure 1.H and 1.I shows the planned (blue) vs post-op (purple) cut bones. Table 1 reports the spatial orientation and position errors.

	FE	VV	IE	AP	PD	ML
Tibia	0.4°	0.1°	0.1°	-0.1 mm	1.2 mm	0.5 mm
Talus	-1.3°	-1.1°	-0.7°	0.3 mm	0.3 mm	-0.6 mm

Table 1: Deviation of post-op cuts to pre-op planning: FE= flexion/extension; VV = varus/valgus, IE = internal/external; AP = antero/posterior, PD = proximo/distal, ML = medio/lateral.

Discussion

These preliminary findings support the efficacy of the adopted automatic methodology and the proposed PSI. Deviation of final cuts placement from the preoperative plan was less than 1.5 degrees in all orientations, providing greater accuracy than the ±3 degrees obtainable with traditional instrumentation and computer navigation [5].

References

1. Gagneet et al., Foot Ankle Int, 40(10): 1160-1165, 2019.
2. Hamid et al., Foot Ankle Int, 38(1): 49-57, 2017.
3. Conconi et al., J Foot Ankle Res, 20;14(1):66, 2021.
4. Conconi et al., J Biomech, 48(12): 2960-2967, 2014.
5. Berlet et al, Foot Ankle Int 35(7): 665-676, 2014.

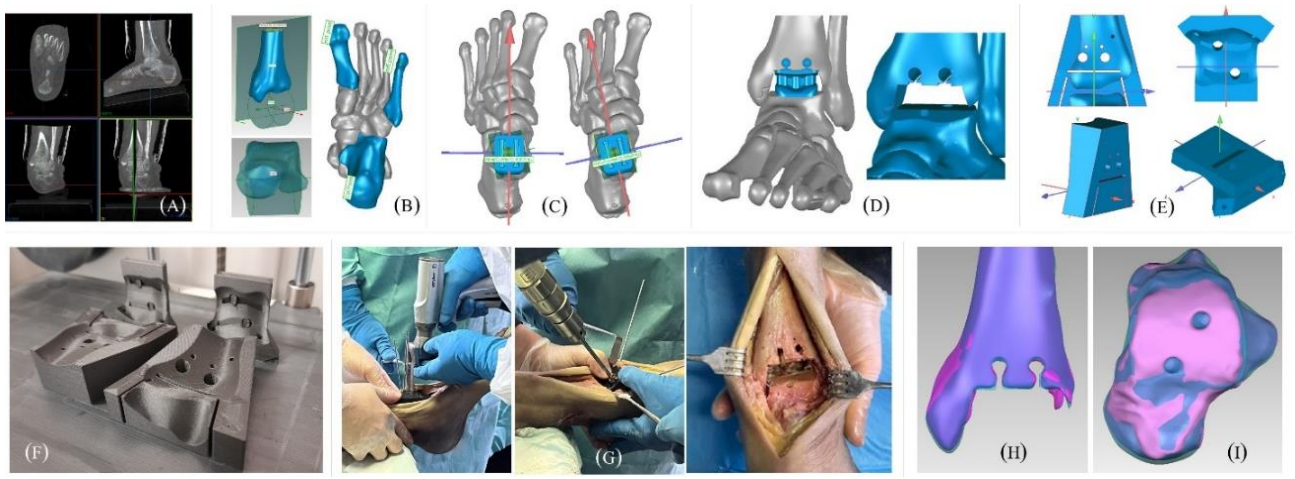

Figure 1: Procedure for TAR planning and PSI design (top row), and experimental validation (bottom row).