Press-fit total knee arthroplasty with a robotic-cutting guide – proof of concept and initial clinical experience

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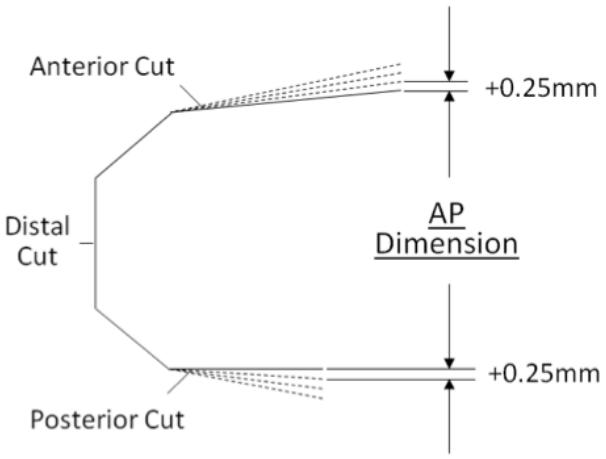
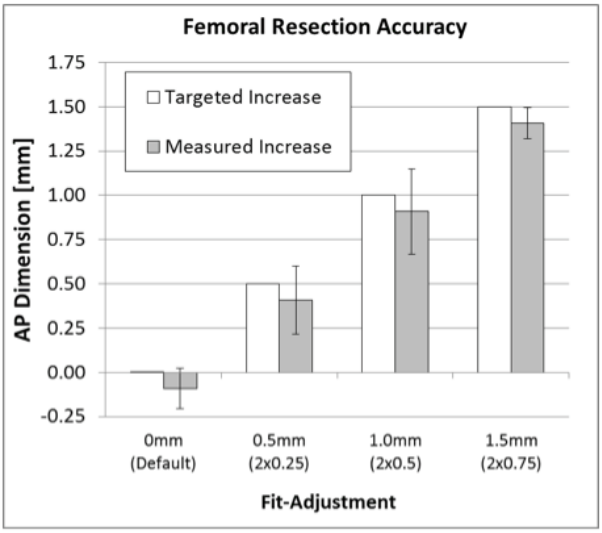
Introduction: Intimate bone-implant contact is a requirement for achieving stable component fixation and osseo-integration of porous-coated implants in TKA. However, consistently attaining a press-fit and a tight-fitting femoral component can be problematic when using conventional instrumentation, even for experienced surgeons. We present a new robotic cutting-guide system that permits intra-operative adjustment of the femoral resections such that a specified amount of press-fit can be consistently attained (patent pending).

System Description: A.R.T. (Apex Robotic Technology) employs a miniature bone-mounted robotic cutting-guide and flexible software that permits the surgeon to adjust the anterior and posterior femoral resections in increments of 0.25 mm per resection, allowing a maximum of 1.5mm of total added press in the AP dimension (figure 1, left).





Methods: The accuracy of guide-positioning and bone-cutting with A.R.T. was assessed in bench testing on synthetic bones (Sawbones®) using an optical comparator.

Evaluation of A.R.T. positioning precision: The individual guide locations for 16 femoral cut positioning sequences (80 guide positions in total) were measured. The data were transferred into a CAD software program (Solidworks Corp., Waltham, MA) and the anterior-posterior (AP) dimensions of the resections were calculated. To simulate actual use conditions and to account for any variability that may occur during the system set-up procedure, the instruments and robotic motor unit were reassembled and recalibrated and the software was restarted before performing each positioning sequence.

Assessment of Cut Accuracy and Implant Fit: Femoral resections were performed with A.R.T. on eight sawbones (two per fit-adjustment setting) and the AP dimensions of the final cut surfaces were measured

using the abovementioned method. Eight sawbones were also prepared using conventional instrumentation (jigs) as controls: four with a 0 mm press-fit block and four with a +0.5 mm specially manufactured press-fit block. After measurement of the bone-cut surfaces a trial component was impacted on bone and the implant fit/looseness parameter (F) was measured according to the method described in [1].

Results: A.R.T. guide-positioning error in the AP dimension was -0.04 ± 0.14mm (mean ± SD). The standard deviation in guide positioning for the distal, anterior chamfer and posterior chamfer resections was 0.03° and 0.17mm.

The average error in the AP dimension between the targeted and measured cuts was -0.14±0.13mm with A.R.T. and 0.7±0.52mm with conventional blocks (p=0.021, figure 1, right).

Mean implant-fit 'F' values were: A.R.T. – 0.50°[0mm]; 0.38°[0.25mm]; 0.03°[0.5mm]; 0.06°[0.75mm]. Conventional – 0.30°[0mm]; 0.11°[0.5mm].

Discussion: A.R.T. guide positioning precision was found to be sub-degree and sub-millimetric, allowing for significantly more accurate (p=0.021) and repeatable (p=0.023) bone resections than conventional instrumentation. In addition, 252 consecutive cases were performed in 2012 by the senior author (C.E. Ponder) using this new software module. In all cases performed using the system, it was possible to achieve a tight and intimate fit between the femoral component and the bone as assessed by visual inspection and the amount of impaction and extraction force required to seat and remove the trial components and final implant. An overview of the surgical technique and authors clinical experience will be provided.

References

[1] Barrera, OA, Haider, H. Garvin, KL. Towards a standard in assessment of bone cutting for TKR, Proc.IMechE-Part-H:J.Eng.Medicine, 2008, 222(H1),63-74.