Anatomy-based patellar tracking in navigated total knee arthroplasty

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Introduction: In computer-aided total knee arthroplasty (TKA), surgical navigation systems (SNS) allow accurate prosthesis component implantation by tracking intra-operatively tibio-femoral joint (TFJ) kinematics after relevant bony landmarks collection [1]. Unfortunately, TKA alters also normal patello-femoral joint (PFJ) kinematics [2], even in case of navigated implant, and an abnormal PFJ functioning results frequently in joint disorders, which may lead to TKA failure. Particularly, in TKA without patellar resurfacing, PFJ kinematics is influenced by femoral/tibial component implantation; with resurfacing this is further affected by patellar bone preparation and relevant component positioning. The standard technique for patellar resurfacing, even in navigated TKA, is based only on the visual inspection of patellar posterior aspect for clamping patellar cutting jig, and on a simple caliper to check for patellar thickness before/after bone resection, i.e. without any computer assistance.

Patellar resurfacing based on patient-specific bone morphology had been assessed successfully in-vitro [3], and also in-vivo in a pilot study [4], though both limitedly to a few cases and to a single TKA design. The final scope was to include such a navigated procedure in the traditional in-vivo navigated TKA, and a relevant procedure has been developed using a current SNS for TKA extended to measure the effects of every surgical action also on PFJ kinematics.

The aim of this study was to report the current experiences in-vivo in two patient cohorts, each implanted with a specific TKA prosthetic design, with patellar resurfacing.

Materials and Methods: Twenty patients affected by primary gonarthrosis were recruited and divided in two patient cohorts of ten subjects each to be implanted with as many fixed bearing posterior-stabilized prostheses (NRG® and Triathlon®, respectively, both by Stryker®-Orthopaedics, Mahwah, NJ-USA) with patellar resurfacing. Fifteen patients were implanted so far, whereas five patients of the Triathlon cohort are awaiting admission to the hospital. All TKA were performed using two SNS (Stryker®-Leibinger, Freiburg-Germany) with standard femoral/tibial trackers and pointer, and a specially-designed patellar tracker. The novel procedure for patellar tracking was approved by the local ethical committee; all patients gave informed consent prior to surgery. This procedure implies the use of a second system, i.e. the patellar SNS (PSNS), with dedicated software for supporting patellar resurfacing and relevant data processing/storing, in addition to the traditional knee SNS (KSNS). TFJ data are shared between the two.

Before surgery, both systems were initialized; the patellar tracker was assembled following a sterile procedure by shaping a metal grid mounted with three markers to be tracked by PSNS only. The additional patellar-resection-plane and patellar-cut-verification probes were instrumented with a standard tracker and a reference frame was defined on each of these by digitization with PSNS. Afterwards, the procedures for standard TKA navigation were performed using KSNS [1]. TFJ survey was performed also with PSNS together with relevant patellar anatomical reference frame definition and PFJ kinematics assessment according to recent proposals [2]. Standard procedures for femoral/tibial component implantation, and TFJ kinematics assessment were then performed after relevant trial components implantation. Afterwards, the procedure for patellar resection was executed. Once the surgeon had
arranged and fixed the patellar cutting jig at the desired position, the patellar-resection-plane probe was inserted into the slot for the saw blade. With this in place, PSNS captured tracker data to calculate the desired level of patellar bone cut and the patellar cut orientation. Then the cut was executed, and the accuracy of achieved resection was assessed using the patellar-cut-verification probe. The trial patellar component was positioned, and, with all three trial components in place, TFJ and PFJ kinematics were captured. Adjustments in component positioning could still be performed, until both joint kinematics were satisfactory. At last, final components were implanted and cemented, and final TFJ and PFJ kinematics were acquired. A sterile calliper and pre/post-implantation lower limb X-rays were used to check for patellar thickness and final lower limb alignment.

**Results:** The assessment protocol was performed successfully in all cases without complications, resulting in 30 min longer on average over the patients with respect to standard TKA. The final lower limb misalignment was within 0.5°, resurfaced patella was 0.4±1.2 mm thinner than the native, and patellar cut was 0.4°±4.1° laterally tilted. Final PFJ kinematics, i.e. after final component implantation and patellar resurfacing, was generally taken the reference normality [5], in both series. This showed a mean range of flexion, tilt and medio-lateral shift of 66.9°±8.5° (mean of minimum-maximum values, 15.6°÷82.5°), 8.0°±3.1° (-5.3°÷2.8°), and 5.3±2.0 mm (-5.5÷0.2 mm), respectively. Significant correlations were found between the internal/external rotation of the implanted femoral component and the range of PFJ tilt (p=0.05; R²=0.41), and between the mechanical axis on the sagittal plane and the range of flexion-extension (p=0.05; R²=0.44) and of antero-posterior shift (p=0.04; R²=0.45) at the PFJ.

**Conclusions:** The results reported support relevance/efficacy of patellar tracking and PFJ kinematics assessment in in-vivo navigated TKA. The encouraging in-vivo results may lay ground for the design of a
future clinical patella navigation system the surgeon could use to perform a more comprehensive 
assessment of the original whole knee anatomy and kinematics, i.e. including also PFJ. Patellar bone 
preparation would be supported for suitable component positioning in case of resurfacing but, 
conceptually, also in not resurfacing if patellar anatomy and tracking assessment by SNS reveals no 
abnormality. In the future if this procedure will be routinely applied in navigated TKA, TFJ and PFJ 
abnormalities can be corrected intra-operatively by more cautious bone cut preparation and correct 
prosthetic component positioning on the femur, tibia and also patella, in case of resurfacing.

References