In-vivo Patellar Tracking After Total Knee Arthroplasty: A Novel Assessment Technique Including Video-fluoroscopy Combined With Standard Gait Analysis.

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Introduction: Tibio-femoral joint (TFJ) kinematics after total knee arthroplasty (TKA) has been largely exploited using several approaches. Unfortunately, although the patello-femoral joint (PFJ) is fundamental for the knee extensor apparatus, postoperative patellar tracking has not been considered with the appropriate care so far [1]. In detail, in TKA without patellar resurfacing, the physiological patellar motion is affected by femoral and tibial component implantation; in case of resurfacing, this motion is further affected by patellar cut execution and related polyethylene component implantation. Furthermore, although TKA is an effective surgical treatment, patients do not recover completely normal functions at the impaired lower-limb after surgery, both in terms of joint kinematics, kinetics, and normal muscle activity in daily living activities [2]. In addition, postoperative patellar maltracking may result frequently in several PFJ disorders and, ultimately, in TKA failure and subsequent revision surgery [1].

It is, therefore, fundamental to assess PFJ kinematics not only intra-operatively during TKA to comprehend in advance the effects of each relevant surgical action on the whole knee [3], i.e both TFJ and PFJ, but also post-operatively at the follow-up to verify if the physiological knee motion has been fully restored. The latter issue has been addressed in the past, but generally by means of not fully appropriate and reliable methodologies. Among available investigation methodologies at the follow-up after TKA, three-dimensional video-fluoroscopic analysis (VFA), originally designed to track femoral and tibial prosthesis components only, has the potential, after suitable adaptations, to track also patellar motion. In addition, standard stereo-photogrammetric gait analysis (SGA) synchronized with two force platforms and electromyography (EMG) allow the thorough functional, kinematic, kinetic assessment of TKA patients at the follow-up together with an complete overview of relevant muscle activity.

The aim of this pilot study was to report the preliminary results of a novel technique using three-dimensional VFA for accurate knee kinematics assessment at the follow-up after TKA by tracking all three prosthesis components, i.e. including also the patellar polyethylene component. Full body functional assessment using standard SGA and EMG were also performed. We expect that combined motion analysis using these three methodologies at TFJ and, now, also at PFJ complex can enhance the comprehension of TKA performances under standard loading conditions of daily living.

Methods: Five patients affected by primary gonarthrosis were recruited to be implanted using surgical navigation procedures with a fixed bearing posterior-stabilized prosthesis (NRG®, Stryker®-Orthopaedics, Mahwah, NJ-USA) with patellar resurfacing. During TKA, before cementing the final patellar polyethylene component, three tantalum beads were inserted in known position in as many component fixation pegs. All patients were also analyzed at six months after surgery using SGA and VFA. This procedure was approved by the local ethical committee; all patients gave informed consent prior to surgery.

SGA was performed using a 8-cameras motion system (Vicon Motion Systems, Oxford, UK) together with EMG (Wave Wireless, Cometa, Milan, Italy) and force platforms (Kistler Instruments, Eienthrurth, Switzerland) via an established protocol for assessing lower limb joint kinematics and kinetics [4] during level walking, flexion (FaG) and extension (EaG) against gravity. On the same day, these motor tasks were also acquired for VFA using a standard fluoroscope device (CAT Medical System, Monterotondo, Italy) at 10Hz and an established technique [5] (see figure). Particularly, the absolute three-dimensional position and orientation (altogether pose) of the femur and the tibia were reconstructed during motion; the patellar pose was also reconstructed by tracking the geometrical model based on the three tantalum beads within the patellar polyethylene, these being fully radiopaque on fluoroscopic images, and calculated with respect to the femur [1]. TFJ and PFJ kinematics were calculated according to established recommendations [6] and a recent proposal [1], respectively. PFJ flexion, tilt and rotation were calculated together with TFJ kinematic variables.

Results: The novel technique using VFA allowed accurate three-dimensional tracking of PFJ kinematics, in addition to standard TFJ, and was successfully combined with SGA and EMG. During walking, very similar kinematics and kinetics patterns were observed between patients in the operated and contralateral lower limbs, the average maximum knee flexions being, respectively, 14.6° and 14.0° at loading response and 51.0° and 52.5° in swing phase. In VFA, PFJ flexion, rotation and tilt ranges during FaG [EaG] in the operated knee were 64.4° [64.4°], 6.7° [6.8°], and 6.3° [8.5°]; corresponding TFJ flexion, ad-abduction
and internal-external rotation were, respectively, 96.0° [96.5°], 4.2° [6.8°], and 9.0° [7.8°].

A larger TFJ adduction and abduction occurred in patients with a larger lateral and medial PFJ rotation, respectively. Patients with a lateral PFJ rotation showed a prolonged activity for the extensor apparatus. Conversely, nearly natural kinematics and kinetics patterns together with a normal muscle activity occurred in patients with a medial PFJ rotation over flexion.

**Discussion:** The results here reported reveal the feasibility of tracking PFJ kinematics using VFA, suitably adapted to address this issue, and the relevance of the synergic combination of this evaluation technique with SGA and EMG for a thorough comprehension of the replaced knee status and impaired lower limb functions. Particularly, PFJ kinematics was here tracked directly and accurately in-vivo for the first time under a number of loading condition of daily living, whereas, the traditional measurements [5] were enhanced by new observations. As an example, the observed abnormal TFJ kinematic and kinetic patterns were found in presence of abnormal PFJ rotations.

Furthermore, this complete functional, kinematic and kinetic assessment of the replaced knee, i.e. of both TFJ and PFJ, and related impaired lower limb can prove soon the restoration, or not, of the physiological functions of the operated knee. More importantly, a early diagnosis of possible postoperative abnormalities at TFJ and/or PFJ would be strategic in order to intervene with still conservative treatments, targeted rehabilitation or less invasive revision surgeries.

Currently, this pilot study is being extended to larger patient cohorts to produce robust statistical results.

**Significance:** This study reports evidence of a novel fluoroscopy in-vivo technique aimed at assessing PFJ kinematics in TKA patients with patellar resurfacing, suitably combined with standard evaluation techniques. This would allow the early diagnosis of possible postoperative abnormalities to be addressed still with rehabilitation or less invasive treatments.

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**References:**

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