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IN-VIVO KNEE KINEMATICS AFTER TOTAL JOINT ARTHROPLASTY. A NOVEL FLUOROSCOPY-BASED TECHNIQUE FOR TRACKING PATELLAR MOTION.

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SUMMARY

Total knee arthroplasty is an effective surgical treatment, although patients do not recover completely normal lower limb joint kinematics and kinetics, and normal muscle activity in daily living activities at the operated knee. Whereas the tibio-femoral joint has been largely exploited in the past using several methodologies, the patello-femoral joint, which plays a fundamental role in the extensor mechanism, has not been considered with the appropriate care. The aim of this pilot study was to report the preliminary results of a novel technique for accurate knee kinematics assessment at the follow-up after total knee arthroplasty by tracking all three prosthesis components, i.e. including also the patellar polyethylene component, using three-dimensional video-fluoroscopy together with full body functional assessment by standard stereo-photogrammetric gait, electromyography and force plate analysis. Five patients recruited for total knee arthroplasty were implanted by means of an advanced navigation technique [3]. During surgery three tantalum beads were inserted into the patellar polyethylene component prior the final cementation. After six months, these patients were assessed using gait, force plate and electromyography analyses, together with a suitable adapted video-fluoroscopy technique. The latter allowed kinematics tracking of patello-femoral joint in addition to standard tibio-femoral joint. Mean patellar flexion, rotation and tilt ranges during flexion and extension against gravity in the operated knee were 64.4° and 64.4°, 6.7° and 6.8°, and 6.3° and 8.5°. Abnormal tibio-femoral joint kinematic and kinetic patterns were found in abnormal patello-femoral rotations. These findings support relevance, feasibility and efficacy of in-vivo patellar tracking using video-fluoroscopy combined with gait analysis.

INTRODUCTION

In the human knee, the tibio-femoral joint (TFJ), both intact and after total knee arthroplasty (TKA) has been largely exploited by various kinematic analyses, whereas the patello-femoral joint (PFJ), which plays a fundamental role in the extensor mechanism, has not been considered with the appropriate care [1]. Particularly, it is well known from the literature how TKA alters not only normal TFJ but also normal PFJ kinematics, the latter being further affected by patellar component positioning in case of resurfacing. Particularly, although TKA is an effective surgical

treatment, patients do not recover completely normal lower limb joint kinematics and kinetics, and normal muscle activity in daily living activities [2]. Furthermore, post-operative abnormal patellar tracking may result frequently in a number of PFJ disorders and, ultimately, in the failure of TKA [1]. It is, therefore, fundamental to assess PFJ kinematics not only intra-operatively during TKA to allow the surgeon to comprehend in advance the effects of each relevant surgical action [3], but also post-operatively at the follow-up under a number of loading conditions to verify if the physiological motion of the whole knee, i.e both TFJ and PFJ, has been fully restored, this having been generally carried out using not fully appropriate and reliable methodologies so far. Among all possible investigation methodologies three-dimensional video-fluoroscopic analysis (VFA), originally designed to track the prosthesis components of the TFJ complex only after TKA, has the potential, after suitable adaptations, to track also patellar motion, whereas standard stereo-photogrammetric gait analysis (SGA) synchronized with two force platforms and electromyography (EMG) allow the thorough functional, kinematic, kinetic and muscle assessment of the patient.

The aim of this pilot study was to report the preliminary results of a novel technique 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, using three-dimensional VFA, together with full body functional assessment using standard SGA and EMG. We expect that combined motion analysis using these three methodologies of the TFJ and, now, also of the PFJ complex can enhance the comprehension of TKA performances.

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 6 months after surgery using SGA and VFA. This procedure was approved by the local ethical committee; all patients gave informed consent prior to surgery.

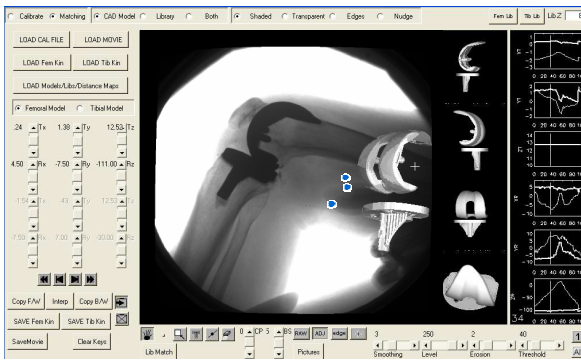


Figure 1: Screenshot reporting the software interface (Kneetrack®, by Banks S., University of Florida, FL-USA) for TKA data processing via VFA from a well representative case. The X-ray image movie, calibration data, and femoral, tibial and patellar CAD models, the latter being based on the three tantalum beads, are loaded. CAD models are matched on bi-dimensional component contour on each X-ray image.

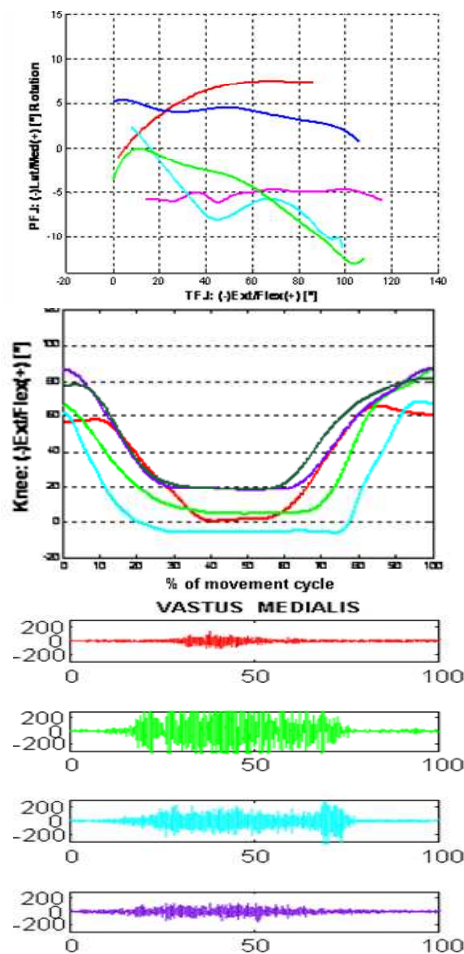


Figure 2: Combined VFA (top), SGA (central) and EMG (bottom) data during EaG from a well representative case.

SGA was performed using a 8-camera motion system (Vicon Motion Systems, Oxford, UK) together with EMG (ZeroWire, Aurion, Milan, Italy) and force platforms (Kistler Instruments, Einterthur, 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, Italy) at 10Hz and an established technique [5] (Fig.1). 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 tracked after identification of the three tantalum beads inserted in the polyethylene component at the time of operation and calculated with respect to the femur [1]. TFJ and PFJ kinematics were calculated according to established recommendations [6] and a recent proposal [1]. For the latter, a patellar reference frame was defined based on the position of the tantalum beads; PFJ flexion, tilt and rotation were calculated as the rotation of the patella, respectively, about the femoral medio-lateral axis, patellar proximo-distal axis, and the floating axis perpendicular to these axes.

RESULTS AND DISCUSSION

The novel technique using VFA allowed successful tracking of PFJ kinematics in addition to standard TFJ and combined with SGA and EMG (Fig.2). During walking, all patients presented very similar kinematics and kinetics patterns 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 and EaG in the operated knee were 64.4° and 64.4°, 6.7° and 6.8°, and 6.3° and 8.5°; corresponding TFJ flexion, adduction and internal-external rotation were, respectively, 96.0° and 96.5°, 4.2° and 6.8°, and 9.0° and 7.8°. Particularly, a larger TFJ adduction and abduction occurred respectively in patients with a larger PFJ lateral and medial patellar rotation. Patients with a lateral patellar 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 patellar rotation over flexion.

CONCLUSIONS

By combining standard SGA, EMG and accurate suitable adapted VFA a thorough comprehension of the replaced knee status is possible. All these methodologies were employed for a complete functional, kinematic and kinetic assessment of the whole knee, i.e. both TFJ and PFJ, and can prove the achievement, or not, of the physiological functional recovery of the operated knee. PFJ kinematics was here tracked directly in-vivo for the first time, whereas, the traditional measurements [5] were enhanced by new observations. Particularly, the results in these patients show how abnormal TFJ kinematic and kinetic patterns were found in abnormal PFJ rotations. The findings support relevance, feasibility and efficacy of in-vivo patellar tracking in VFA. Currently, this pilot study is being extended to larger patient cohorts to produce robust statistical results.

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