PATIENT-SPECIFIC ESTIMATION OF PATELLAR STRAINS AFTER TOTAL KNEE REPLACEMENT

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Introduction

Previous studies suggested that increased postoperative patellar strain after resurfacing in Total Knee Replacement (TKR) is a possible cause of complications development, such as patellar fracture or anterior knee pain (AKP). However, patellar resurfacing is usually overlooked in TKR planning and surgeons do not have special tools to estimate possible strain levels in postoperative patella, and, thus, risk of complications. On the other hand, the knowledge on the patellar strain levels experienced by TKR patients during daily activities is also sparse.
The aim of this study was to evaluate patellar strain in retrospective TKR patients using validated patient-specific numerical models of squat. Correlation between predicted strain and patient data, such as body weight, volume of resurfaced bone and its density that can be easily obtained during preoperative planning, was further analyzed.

Methods

Seven TKR patients (4 female, 3 male, age 68 ± 8, weight 87 ± 17 kg, height 165 ± 8 cm) at least one year after the surgery were chosen. Patients received cemented posterior-stabilized knee prosthesis (F.I.R.S.T.; Symbios, Yverdon-les-Bain, Switzerland) with patella resurfacing. None of the patients had complications related to the TKR and patella after one year follow-up. Seven patient-specific TKR models were created based on the patient pre and postoperative data [1]. Each model was decoupled in two levels: the knee and the patella (Figure 1). The knee model replicated loaded (body weight) squat and estimated kinematics and forces acting on the patella, which were then used in the patella model as boundary conditions to predict bone strains. The patellar bone was modeled as anisotropic linear elastic material based on morphology-elasticity relationship [2]. Patellar bone volume fraction (ρ) was obtained from patient CT [1], while the morphology (fabric tensor) was derived from μCT images of a cadaveric patella using a validated template registration method [3]. Octahedral shear strain was calculated for each patella at 60° of knee flexion. Peak strains (highest strain in 99% of bone volume with lowest strain) and bone volumes above 1% and 2% of strain were calculated and compared. Correlation between peak strains and patient parameters such as body weight (BW), bone volume (V) of resurfaced patella and its mineral density (BMD) was analyzed.

Results

Peak strains were 1.3 ± 0.6% (0.53 - 2.28%). Bone volume above 1% strain was 6.9 ± 8.6% (0.01 - 24%). Only one patella reached 2% strain, within 2.4% of the bone volume. Peak strains were correlated to the ratio (BW)/(V×BMD) ($r = 0.84$, $p = 0.017$), and to BMD ($r = 0.81$, $p = 0.028$). BMD was lower in females (0.40 ± 0.08 g/cm^3) than in males (0.49 ± 0.06 g/cm^3).

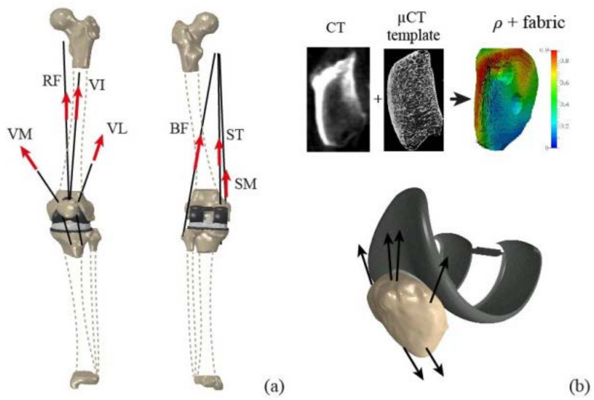

Figure 1: The knee (a) and the patella (b) models.

Discussion

All predicted peak strains were within 1% and 2%, except for one patient. These strain thresholds were considered since they are often associated with bone yielding and micro-damaging. As none of the patients had complications related to the patella during follow-up, it may be suggested that estimated strain levels and strained bone volumes are in the acceptable range. However, longer patient follow-up is needed for stronger conclusions. A significant correlation was found between strain peaks and the ratio body weight to product of the patellar volume and density. In current clinical practice, the examination of patellar density and the preoperative planning of the patellar cut are not standard procedures. To improve patellar outcome in TKR, this additional examination might be useful. The proposed ratio could be used in everyday practice, but should be first assessed on more patients, especially pathologic cases.

References

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