IN VITRO BIOMECHANICAL STUDY OF VARIATION OF DEFORMATION IN THE TIBIAL PROXIMAL EPIPHYSEAL CANCELLOUS BONE AFTER FEMORAL TORSION DISORDER

Stéphane Sobczak, Bruno Baillon, Véronique Feipel, Serge Van Sint Jan, Patrick Salvia, Marcel Rooze

1 Laboratory of Anatomy, Biomechanics and Organogenesis (LABO), Université Libre de Bruxelles (ULB), Belgium.
2 Laboratory for Functional Anatomy, Université Libre de Bruxelles (ULB), Belgium.
3 Departments of Orthopedics and Traumatology Surgery, Hôpital Erasme, Cliniques Universitaires de Bruxelles, Université Libre de Bruxelles (ULB), Belgium.

*Corresponding author: ssobczak@ulb.ac.be

SUMMARY

Osteoarthritis (OA) of the knee is a degenerative disease mainly found in an elderly population. Valgus deformity seems to be directly related to lateralised gonarthrosis. Contradictory outcomes of surgical series are published in the literature and reported satisfactory and unsatisfactory long term results. Lower limb torsions disorders have been considered as being another factor inducing gonarthrosis. This paper presents an in vitro study aiming at quantifying the relationships between femoral torsion (medial and lateral) induced by low femoral osteotomies and the deformation of the cancellous bone of the proximal tibial epiphysis (CB TPE) on five left fresh-frozen lower limbs. Six measurement elements (ME), including strain gages, were introduced into CB TPE to measure relative deformation. Deformations were significantly influenced by torsion conditions and range-of-motion (ROM) for most measurement elements. Globally, CB TPE deformation in the lateral compartment increased during lateral torsion and decreased during medial torsion. The opposite behaviour was observed in the medial compartment.

INTRODUCTION

Knee osteoarthritis (OA) is a common degenerative pathology found generally in an elderly population. Approximately 30% and 10% of the population over 65 and 55 years of age respectively is affected by this health problem. Valgus deformity is directly related to lateralised gonarthrosis, but a number of patients develop precociously a lateralized gonarthrosis without presenting a deformation in the frontal plane. The association of torsions disorders of the lower limb was mentioned as being a factor inducing a lateralized gonarthrosis [1]. In the literature there is a lack of quantified data to better understand the relationships between bone alignment, osteotomy surgery, local joint pressure and joint kinematics. This study for the first time shows the results of an in vitro study aiming at quantifying the outcome of femoral torsion disorder of the femoral distal epiphysis [3]. Medial torsion (MFT) and lateral torsion (LFT) were performed for various deviation angles from 6° to 18°. Deformation variations in the cancellous bone of the proximal tibial epiphysis were analyzed using six embedded strain gages. The objective of the study was to contribute to a better insight on the relationships between femoral torsion osteotomy and cancellous bone deformation.

METHODS

Specimens

Five left fresh-frozen lower limbs (mean age: 84 (9) years; 3 males, 2 females) were obtained from the ULB Body Donation program. Thawing occurred at room temperature 24 hours before the experiment. Each specimen included a full lower limb with its hemi-pelvis. None of the specimen underwent any surgery prior to this study. Each specimen was submitted to the following experimental protocol. Computed tomography (CT, Siemens SOMATOM, helical mode, slice thickness = 0.5 mm, inter-slice spacing = 1 mm) was performed in neutral position to evaluate the lower limb alignment, and possible deviation, in the frontal and transversal planes. Femoral torsion was evaluated by the angle between the proximal and distal femoral axes. The pelvis and femur were rigidly mounted on the experimental jig in anatomical position (Figure 1). The distal tendons of 8 muscles of interest were carefully dissected and cut at their insertions. The objective was to quantify the deformation of the cancellous bone of the proximal tibial epiphysis after different torsion disorders.

Figure 1: Experimental setting showing a specimen mounted on the experimental jig in anatomical position. A: LVDTs set along muscle lines of action. B: femoro-tibial electrogoniometer. C: femoro-patellar electrogoniometer.
distal musculotendinous junction. A fishing wire (Surflon®; Nylon coated, American Fishing Wire, 90 Lb., USA) was attached to each dissected tendon by a trained orthopaedic surgeon. Each fishing wire ran proximally through tunnels drilled into the bone at the level of the related muscle origin to allow joint loading following the physiological muscle lines of action. Total loading was 300 N. Two 3D electrogoniometers were used simultaneously to measure femoro-patellar and femoro-tibial 3D joint kinematics. Six measurement elements (ME) were used in this study to measure CB_{TPE} deformation [2]. ME location was standardized. Six calibrated tunnels (Ø: 4.2 mm) were drilled into the cancellous bone underlying the tibial plateau at 10 mm below the joint line. ME standardization was obtained using strict definitions describing anatomical landmark locations observable on the available 3D models. The localisations of ME are the following: ME 1: antero-medial strain gage; ME 2: medial strain gage; ME 3: postero-medial strain gage; ME 4: postero-lateral strain gage; ME 5: lateral strain gage; ME 6: antero-lateral strain gage.

In vitro surgical setting

In vitro surgery used a specially-built control system (CS) to keep track of the femoral osteotomy amplitude in MFT and LFT. The osteotomy was performed by a trained surgeon 10 cm above the knee joint line. The analyzed deviations of the distal femoral diaphysis were 6°, 12° and 18° for both kinds of deviation (MFT and LFT). The order of conditions was randomised, except for the intact condition [2].

Data collection

For each of the above-mentioned osteotomy deviation, three repetitions of two cycles of flexion-extension movement were performed. Measurement started with the knee in full extension maintained by the muscle loading. Flexion was then performed manually by pushing with an opened hand on the anterior part of the distal shank. All data were then normalized to femoro-tibial ROM.

Statistical analysis

Kolmogorov-Smirnov’s and Levene’s test were used to make sure of normality and the homogeneity of variance of our variables. A one-way ANOVA was used on the mean ME deformation over the entire range of motion (0°-90° of knee flexion) and A two-way ANOVA for repeated measurements was used to investigate the effect of surgical conditions and knee ROM (mean deformation between 0°-30°, 30°-60° and 60°-90°) on measured variables (ME). In function of the results of these statistical tests, a Post-Hoc LSD test was used. All above statistical analysis was performed using Statistica© software with a confidence interval of 95%.

RESULTS AND DISCUSSION

Deformation over the entire flexion range

No statistical modifications (p>0.05) were observed between all experimental condition and for all ME.

Deformation for sequential 30° knee flexion ranges. Statistical modifications (p<0.01) were observed for all ME. No interaction between experimental conditions and knee flexion was observed.

ME1: Statistical modifications were observed between intact condition and TFM6°, 12° and TFL6° between 30° and 60° of knee flexion. Note that the tendency of all experimental conditions decreased local bone deformation.

ME2: No statistical modifications were observed between intact condition and experimental deviation conditions for all part of knee flexion. Extreme experimental conditions (TFM 12°, 18° - TFL 12°, 18°) were statistically different after 30° of flexion. Note that TFM conditions increased bone deformations and TFL conditions decrease bone deformations.

ME3: Statistical modifications were observed between extreme experimental conditions (TFM 18° - TFL 12°, 18°). TFM conditions increased bone deformations and TFL conditions decreased bone deformations. No statistical modifications were observed between intact condition and experimental conditions.

ME4: No statistical modifications were observed between intact condition and all experimental conditions.

ME5: Statistical modifications were observed between intact condition and experimental conditions (TFM 12°, 18°, TFL 12° and 18°). Note that TFM conditions decreased bone deformations and TFL conditions increased bone deformations.

ME6: No statistical modifications were observed between 0° and 30° of knee flexion. After 30° of flexion TFM 12° was significantly different from TFL 12° and TFL 18°. Note that TFL conditions seemed to increase bone deformations and inversely for TFM conditions.

These different results show that the intact condition was rarely different from other experimental conditions, but extreme conditions were globally different from each other for most ME (not for ME1 and ME4). The global tendency was that TFL seemed to increase CB_{TPE} deformation in the lateral compartment, while TFM increased bone deformation on the medial aspect of the tibial plateau. Note that this protocol does not consider the ground reaction force.

CONCLUSIONS

This study reported for the first time an experimental protocol aiming at quantifying the relationships between alterations of low femoral torsion and CB_{TPE} deformations. The main results of this study indicate that these results do not fully confirm previous, not quantified, clinical observations that high medial femoral torsions induce a lateralized gonarthrosis by increasing the medial tibio-femoral constraints. The results of this study do not support the statement that knee torsion disorder could explain clinical gonarthrosis observations, and suggest that other anatomical disorders (e.g., soft tissue imbalance) are probably involved in the pathological process.

REFERENCE