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Femoral fixation strength of device-free isoanatomical bone-patellar tendon-bone single-bundle ACL reconstruction – a biomechanical study

Burger LD[1], Arnold MP[1], Göpfert B[2], Wirz D[1,2], Meyer P[1], Hirschmann MT[1]
[1] Department of Orthopaedic Surgery and Traumatology, Kantonsspital Bruderholz
[2] Laboratory of Biomechanics & Biocalorimetry (LOB[2]), University of Basel

Background

Implant-free fixation methods such as the A3B-technique (Anatomical Bruderholz, Burkart, Biedert) are increasingly popular. A3B achieves femoral fixation using a conoid shaped bone block in a conoid shaped tunnel. This study investigated the graft slippage and the strength of femoral press-fit fixation under cyclic and ultimate loading. We hypothesized that press fit fixation provides at least equal or higher ultimate strength of fixation than published values for interference screw fixation.

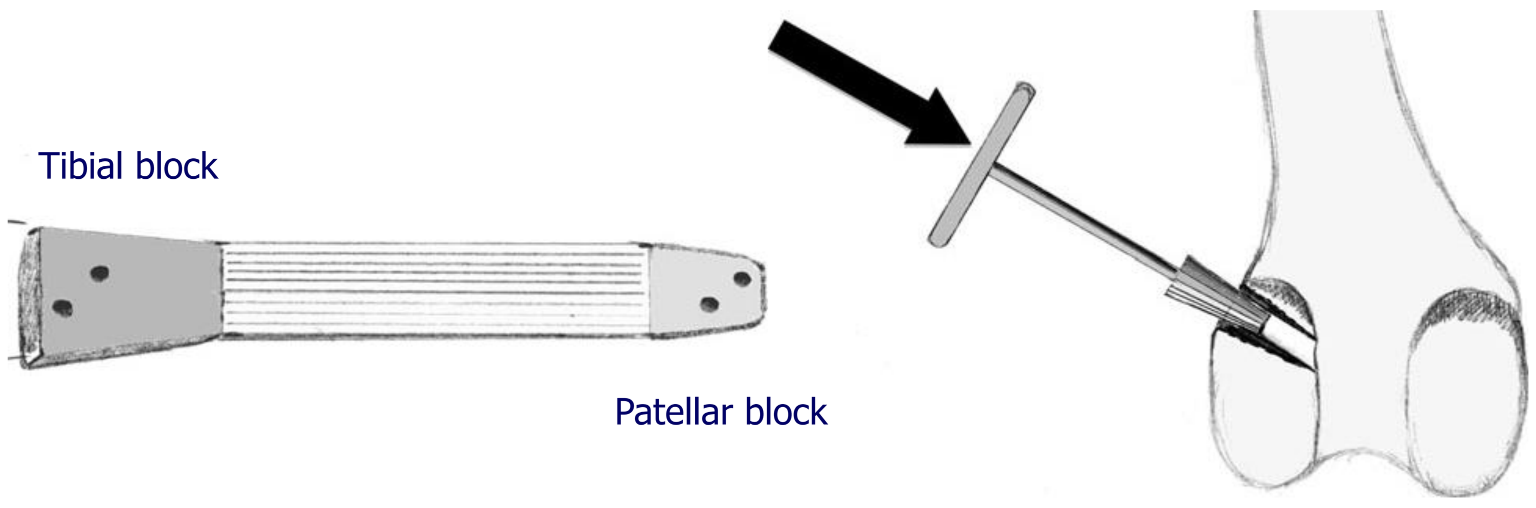

Figure 1:
principle of A3B fixation; Conoid shape of bone blocks and femoral tunnel

Materials and methods

9 fresh frozen knees were obtained from an accredited tissue bank and thawed at room temperature over night. Standardized harvesting of the B-PT-B graft was performed. Stripped of all soft tissue, the femora were cemented into steel rods and fixed with 2 screws for rotational stability. Femoral tunnels were drilled in anteromedial bundle position at 9.30 or 2.30 o'clock respectively. The grafts were inserted into the femoral tunnel and the steel rods were mounted on a MTS 858 Bionix® testing machine. The femoral tunnel was oriented 45° to the horizontal plane, in order to mimick natural angulation of the knee during walking. The tibial bone block of the graft was fixed to the axial cylinder of the testing machine using a deep-freezing technique with liquid CO_2. Optical tracking markers were placed on the femora, tendons and bone-blocks. A Vicon™ motion capture system was used to assess 3-dimensional micro-motion of the bone and graft slippage. Preconditioning of the grafts was performed with sinusoid tensile loading in 2x10 cycles at 1Hz between 10N-52N and 10N-148N respectively. Then the grafts were put under cyclic tensile loading for 1000 cycles at 1Hz between 70N and 225N. Ultimate load to failure was measured at an axial cylinder speed of 1m/s.

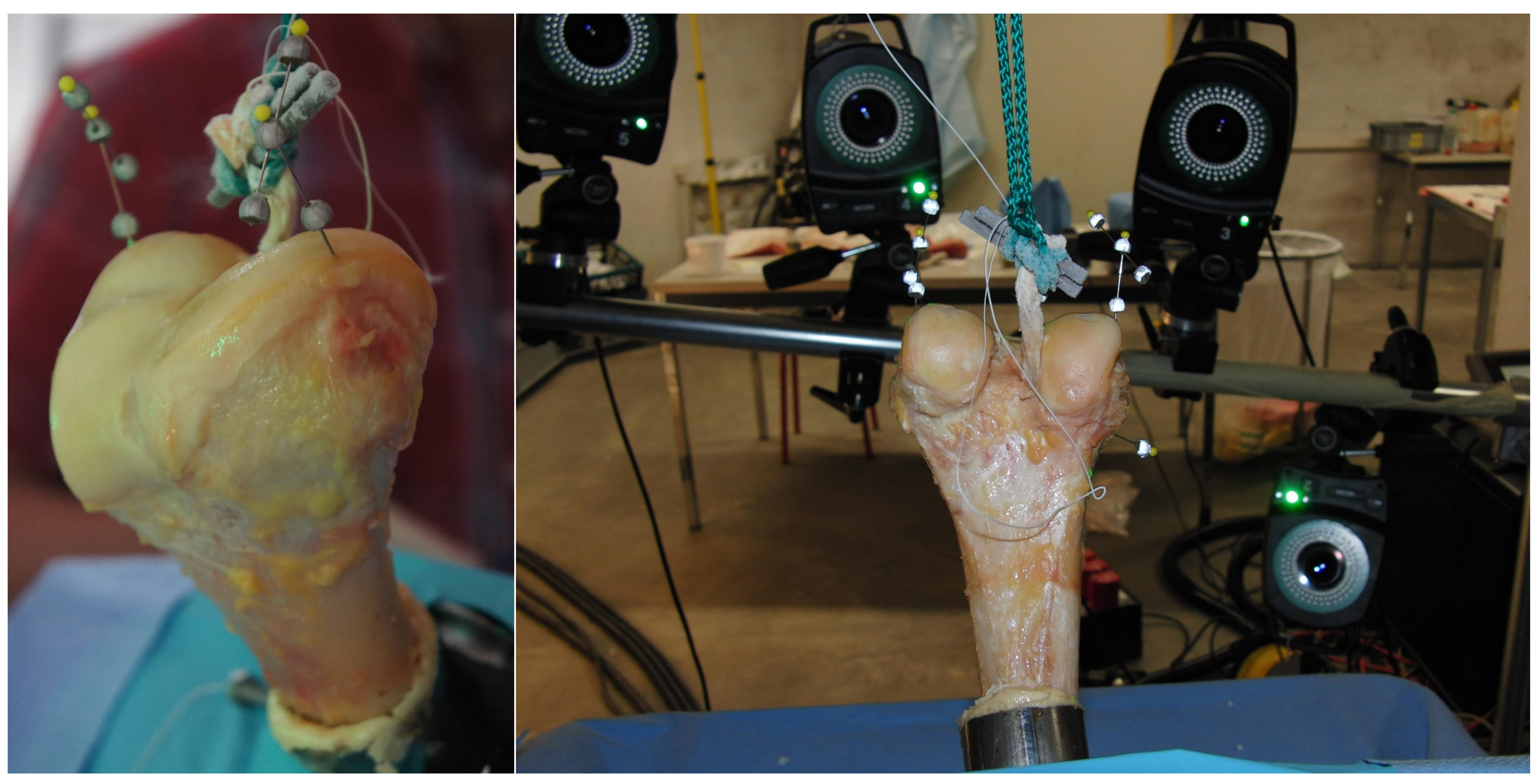

Figure 2:
Configuration of the specimen for the ultimate load to failure test. Vicon markers were placed on the femur and boneblock, the graft was frozen to metal rods with liquid C02. In the background are the Vicon cameras.

Results

The ultimate load test revealed two characteristic patterns of failure. At ultimate failure load, in 4 knees the tendon ruptured (G1, graft failure) while in 5 knees the bone block was pulled out of the femoral Tunnel (G2, block pullout). The median of ultimate force for all grafts was 852N, R=448-1349N. G1 showed a clearly higher pullout force than G2 (graft failure n=4, M=883N, R=448-1349, vs. block pullout n=5, M=684N, R=469-1087).
A typical progress of Graft slippage over the course of the 1000 cycles, independent of ultimate failure mechanism, showed in 7 out of 9 knees. In the preconditioning phase and the following 100 cycles a settling process of the bone block occurred. Once the block had settled, graft slippage asymptotically closed in on a maximal value, however 78.6% of total graft slippage happened in the first 100 cycles. Graft slippage after 1000 cycles varied around 4.02mm (R, 1.3-9.8mm) between the specimens.
Due to an error in measurement, 2 knees could not be included into the analysis of graft slippage.

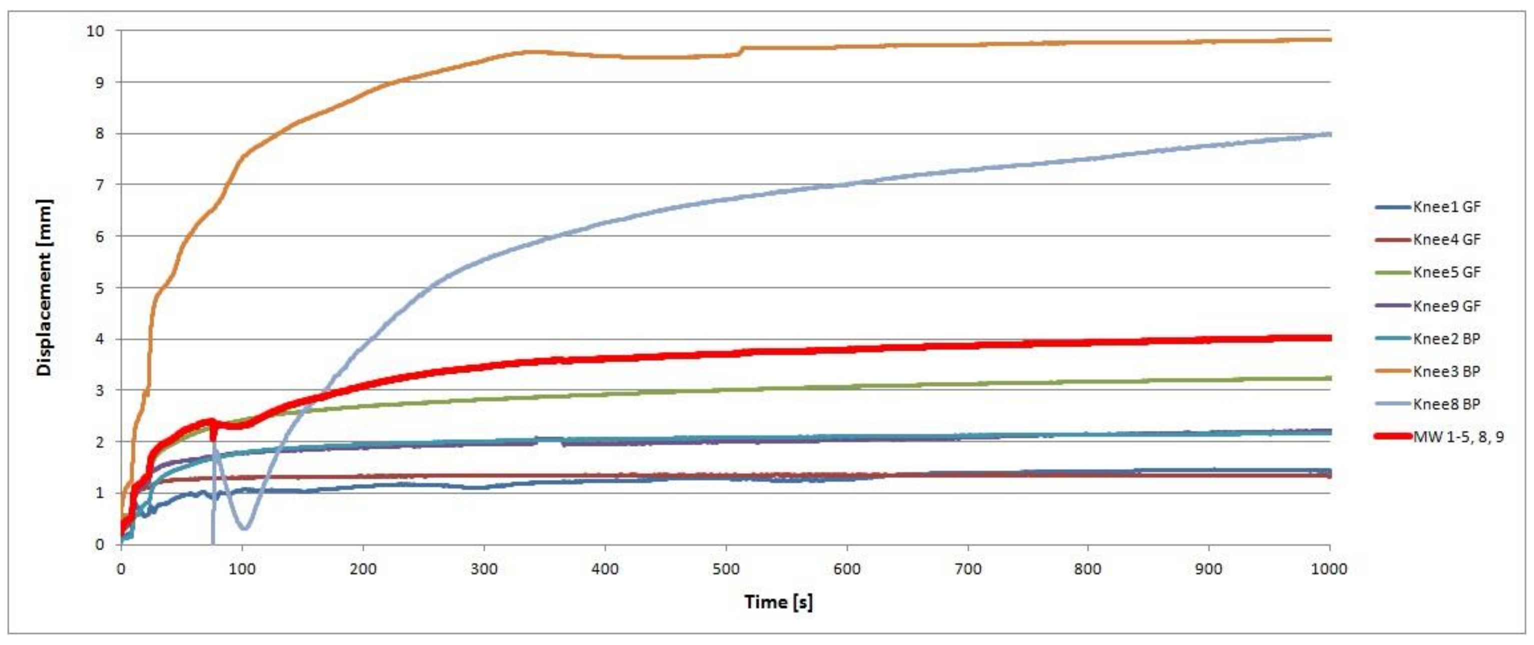

Figure 3:
Asymptotical course of Graft slippage in mm over 1000 cycles. 78.6% of total GF occured within the first 100 cycles, 87.8% within the first 200 cycles.

Conclusion

The implant free press-fit fixation method presented here provides excellent primary stability with ultimate failure pull out forces equal to or better than published results for interference-screw fixations (362N-621N).

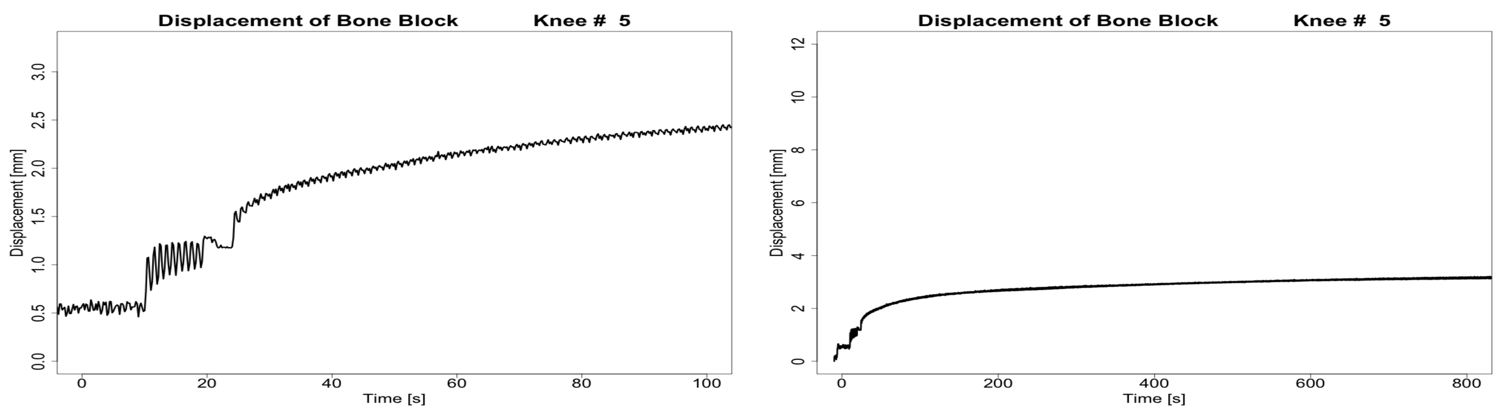

Figure 4:
Typical settling process within the first 100 cycles including the preconditioning phases, compared to the rest of the cyclic loading. (Note the difference in scales)

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References

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