Isometric Placement of a Synthetic ACL Graft

INTRODUCTION: The use of synthetic ligaments in ACL reconstructions first came about in the 1980s and although some biomechanical testing showed promising results, they were generally not very successful. Recent improvements in artificial ligaments have given rise to the use of these ACL substitutes.

It has been shown that under certain conditions an artificial ACL reconstruction can be successful. However, the ligament must be made of polyester, the intra-articular part must be a multi-filament strand and the surgical technique must ensure minimal stresses be placed on the ligament during knee motion [1].

Isometric placement of the graft requires the femoral and tibial tunnels be positioned such that the graft experiences the least change in length over the range of normal knee motion. Synthetic fibres lack elasticity and therefore must compensate for this by architectural means. Isometry of the synthetic graft ensures that it undergoes minimal cyclic strains and hence minimal stresses. This is important to the integrity and hence success of the graft, particularly for synthetic grafts such as the ligament advanced reinforcement system (LARS).

This study compared three commonly used graft insertion techniques with regards to isometricity. Also, isometric behaviour as a function of femoral insertion point was investigated in order to better understand graft isometric techniques.

METHODOLOGY: Following ethical approval, four fresh-frozen, cadaveric lower limbs with no apparent osteoarthrits or anatomic deformity were sourced in preparation for kinematic testing. fiducial markers were placed in the femur and in the tibia of each lower-limb. These were CT-scanned at a resolution of 1 x 1 x 1.25mm. The femurs and tibias were then segmented using a semi-automated algorithm in Amira (ZIB, Berlin). Local femur and tibia coordinate systems were defined using bony landmarks according to Grood and Suntay’s methods.

The same cadaveric specimens were then prepared for passive kinematic testing. In each case, the femur was positioned and held firmly in a vice. Rigid body sensors were placed in both the femur and the tibia and connected to the data acquisition unit of the Optotrak Certus motion capture system (NDI, Waterloo, Canada). The knee was taken though passive knee flexion and extension over a range of 0-90 degrees. The tibia sensor was programmed to record three-dimensional coordinates, with respect to the femur sensor. This raw data was processed and kinematics of the knee joint were calculated and presented with reference to the clinical coordinate systems.

Three different ACL graft positions were evaluated, all of which were determined using sagittal views for the femoral side. These were the JP Laboureau [3], Bernard-Hertel [4] and the Charlie Brown (anatomic) methods. The JP Laboureau method overlaid a circle over the posterior femoral condyles such that it covered 140° of the condyles. The centre of the circle is then taken as the isometric point (Figure 1). The Bernard Hertel method uses a quadrant grid overlaid on the posterior femoral condyle to identify the isometric point. The coordinates are: t=25%, h=29% (Figure 1). The Charlie Brown method also uses the quadrant; however its coordinates are t=29%, h=38%. The tibial point for all three methods was either at 50% or 43% of the AP distance of the plateau and positioned in the centre of the ACL footprint in the ML direction.

For each of the three methods, the distance between the femoral and tibial insertion points was calculated (as a straight line) for each time point in the passive flexion-extension cycle. The change in the distance was calculated relative to the full extension position. Additionally, all the points on the Bernard-Hertel (Quadrant) grid were analysed for each knee and a map of the level of isometric behavior based on the hypothetical position of the femoral insertion point of an ACL graft. Colour maps were generated using a script written in Python. These colour plots show the level of isometric behavior depending on femoral insertion location (Figure 2).

RESULTS: In all four specimens, the most isometric region was a band which spread from approximately the mid to deep end of the Blumensaat’s line down to the shallow-inferior end of the femoral condyle (green region in Figure 2). This was consistent with other studies [6,7].

DISCUSSION: The JP Laboureau method for the implantation of synthetic grafts proved to most functionally isometric insertion point for the ACL. The other two methods were less isometric and undergoing laxities of more than 3mm. However, this is still more desirable than having the graft undergoing excessive tensions. These results provide a visual understanding of location of graft insertion and the corresponding isometric behaviour. Correct graft positioning is critical to graft integrity and ACL reconstruction success.

SIGNIFICANCE: Femoral tunnel placement affects clinical outcome of ACL reconstructions. This study assists the surgeon in selecting a technique based on graft isometric behaviour.