Effect of Graft Rotation in High Tibial Opening Wedge Osteotomy Alignment for Medial Knee Arthritis

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Introduction: The opening or closing wedge tibial osteotomy is a surgical procedure used to correct leg malalignment and/or deformity in many patients. Classically, tibial wedge osteotomies have served to correct varus/valgus (V/V) knee deformity, and to relieve mechanical axis loading imbalances that can result in pain, accelerated cartilage wear and immobility. Often however, bi-planar deformity exists and there is the need to simultaneously correct for both V/V angle and anterior/posterior (A/P) slope. In addition, the incorporation of mild A/P angulation could be prescribed to offload painful areas of damaged or diseased cartilage surfaces in the knees. This study investigates a novel technique whereby tibial wedge axial rotations are combined with opening wedge osteotomy techniques to address both proximal tibial V/V angle and A/P tibial slope in an experimental Sawbone model.

Materials and Methods: Five femoral-tibial Sawbone (Pacific Research Laboratories, WA, 1179-1, Left, Medium) systems were procured. The model was aligned in double-leg stance, distally potted in acrylic, and placed in an orthogonal alignment frame (Figure 1a). Angular reference wires were inserted through the proximal tibia in the medial/lateral (M/L), A/P, and proximal/distal (P/D) directions. An opening wedge osteotomy was then produced according to surgical guidelines (figure 1c). Experimental wedges with 10, 12.5, 15 and 17.5 mm medial heights (as referenced in clinical practice) were produced from donor limbs and inserted into the osteotomy in 0° of internal/external (I/E) rotation. The proximal tibia was re-attached to satisfy surgical criteria of minimal cortical bone overhang and minimal I/E rotational offset with respect to the distal tibia. Tri-planar photography was used to record initial wedge rotation and proximal tibia angulation. Wedges were then incrementally rotated through a range of 90° (external) and -90° (internal) rotation with respect to the tibial base. Angles were determined to within ±1° and the effects of tibial wedge rotation on resulting medial wedge height, tibial V/V orientation and tibial A/P slope were correlated.

Results: Wedge medial heights of 10, 12.5, 15 and 17.5 mm produced initial valgus corrections of 11.9°, 15.3°, 18.7° and 21.5°, greater than surgically expected. Tibial wedge rotation was found to significantly affect resulting proximal tibia orientations, with V/V angulations agreeing well with 2nd ($R^2 > 0.982$) order polynomial models and A/P angulations agreeing well with 2nd ($R^2 > 0.969$) order polynomial models. For all wedge sizes, wedge internal rotations were correlated with increased tibia anterior slopes, and wedge external rotations were correlated with increased tibial posterior slopes. Increases in wedge I/E rotation were correlated with reductions in apparent medial wedge height and initial valgus angular correction. Proximal tibia re-alignment following wedge placements was consistently internally biased, ranging from 2.0±1.9° with the 10 mm wedge, to 4.4±2.5° for the 12.5 mm wedge. Increasing wedge rotation was correlated with increasing wedge cortical protrusion due to non-spherical in cross-sectional areas. The use of oversized wedges, with appropriate internal/external rotational offsets was sufficient to satisfy specific combinations of apparent medial wedge height and V/V angulation, while also allowing for the incorporation of A/P slope angulations. As an example, in figures 2-3 below, the red arrows show that the use of a 17.5 mm wedge rotated internally ~50° simultaneously produces a 15° valgus and 18° anterior slope correction.

Discussion: This study shows that the use of oversized wedges with internal-external rotational offsets can be used to correct for the primary V/V mechanical axis deformity and additionally influence tibial anterior-posterior slope. The combined incorporation of V/V and A/P realignment with a single rotated wedge is a potentially powerful tool for use in surgery, as there is often the need to offload damaged or diseased cartilage surfaces either anteriorly or posteriorly in the knee joint. The results of this study can be utilized to establish an osteotomy rubric such that pre-operative surgical planning can incorporate a range of desired V/V and A/P rotational corrections with the predetermined selection of wedge height and rotation. The incorporation of rotation into the wedge placement is a relatively simple procedure that is both measurable, and tailorable, offering the surgeon added flexibility during the surgical procedure. The measure of "medial height" should be used with caution, as this measure is not independent of tibial geometric width, which will influence resulting angular corrections. Additional work will consider the use of a computer-generated model for advanced analysis of complex wedges geometries and patient specific anatomical modeling.

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