

# The Effect of Posterior Tibial Slope on Tibiofemoral Joint Biomechanics: An In-Vitro Analysis

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**INTRODUCTION:** High posterior tibial slope (PTS) is a well-established risk factor for graft failure after anterior cruciate ligament (ACL) reconstruction and primary ACL insufficiency. In patients with high tibial slope who have failed primary, revision, or re-revision ACL reconstruction, tibial slope reducing anterior closing wedge osteotomy has emerged as a viable surgical option. Several biomechanical studies have demonstrated that decreased posterior tibial slope results in decreased forces across the ACL, but the effect of a tibial closing osteotomy on changes in tibiofemoral joint contact forces, associated with long-term changes in cartilage tissue, have not been quantified. The objective of this study is to quantify the effects of high and low posterior tibial slope (by way of anterior closing and opening wedge osteotomies) on tibial plateau contact mechanics of human cadaveric knees during simulated standing and as a function of knee flexion. We hypothesize a lower tibial slope will result in anterior translation of the center of contact and an increase in peak contact stress while a higher tibial slope will translate contact on the tibia posteriorly and decrease contact stress.

**METHODS:** Nine knees (8 males, 1 female, 25-73 years, 114-197 lbs.) were denuded of skin, subcutaneous fat, muscle, and the patella, while preserving the cruciate ligaments, collateral ligaments, and capsule. The majority of the knees were male due to limited supply of cadaveric donors sourced during the project. The femur and tibia were cemented into place using a custom fixture, and the knees were mounted on a robotic test system [VIVO, AMTI] programmed to apply forces and moments to mimic level standing. An electronic, intra-articular pressure sensor [Model 4011, Tekscan] was calibrated and attached across the tibial plateau of each knee. All knees were confirmed to have an intact ACL. 500 N of compression was applied to each knee for each condition, and testing was performed at 0°, 15°, 30°, and 45° of flexion. Anterior high tibial osteotomy was performed using a standard supra-tubercle approach to create a decreased posterior tibial slope. For an increased posterior tibial slope, an opening wedge osteotomy was performed using fluoroscopy and standard Kirschner wires (K-wires) for guidance. A 7° polymethylmethacrylate (PMMA) cement wedge was fashioned to support the opening wedge and the osteotomy was fixed using bone staples. The closing wedge osteotomy (for decreased PTS) was performed by removing the 7° wedge of tibial bone using fluoroscopy and K-wires for guidance. Keeping the posterior tibial hinge intact, the wedge was closed, and the osteotomy was secured using bone staples for fixation. Posterior tibial slope was quantified using radiographs. The following contact mechanics data were quantified: position of contact (calculated as weighted center of contact (WCoC)) and peak contact stress for the medial and lateral compartments of each knee for each condition. Simple t-tests were performed between the increased and decreased posterior tibial slope conditions at each flexion angle for both WCoC and peak contact stress.

**RESULTS SECTION:** Compared to the intact state, an increased posterior tibial slope resulted in a posterior translation of the WCoC for both medial and lateral compartments (**Figure 1**), of an average 1.3mm (range 1.1-1.4, SD, 0.1) in the medial compartment and 2.8mm (range 1.7-3.5, SD, 0.8) in the lateral compartment. A decreased posterior tibial slope resulted in an average anterior translation of 4.1mm in the WCoC in the lateral compartment (range, 3.7-4.7, SD 0.5) and a posterior translation in the medial compartment of 1.8mm (range 1.4-2.1, SD 0.2) for all flexion angles compared to the intact state (**Table 1**). Significant difference in WCoC difference between increased and decreased tibial slope was only detected in the lateral compartment. A statistically significant increase in average peak contact stress occurred at 30° and 45° of knee flexion in the lateral compartment when the slope was decreased (**Figure 2**). Otherwise, there were no statistically significant changes in peak contact stress for either the medial or lateral compartment between the increased and decreased slope states at all flexion angles (0°-45°).

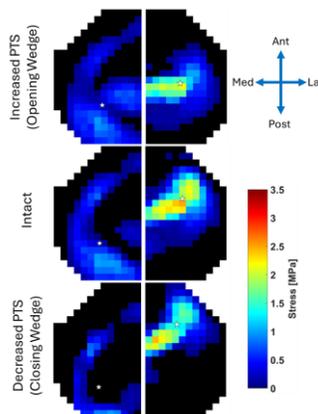
**DISCUSSION:** By way of a cadaveric study, augmented with pressure sensors, we accepted our hypothesis that low posterior tibial slope (by way of anterior closing wedge osteotomy) resulted in anterior translation of the weighted center of contact in the lateral compartment, while high posterior tibial slope (from anterior opening wedge osteotomy) translated contact on the tibia posteriorly in both compartments. Except for the lateral compartment at 30° and 45° flexion, there were no other significant changes in peak contact stress for either the medial or lateral compartments between the increased and decreased slope states.

**SIGNIFICANCE/CLINICAL RELEVANCE:** The study outlined above is the first of its kind to assess tibiofemoral joint biomechanics following high tibial anterior closing wedge osteotomy and anterior open wedge osteotomy. The results may have significant implications for the potential long-term health of the tibiofemoral joint in this select group of patients.

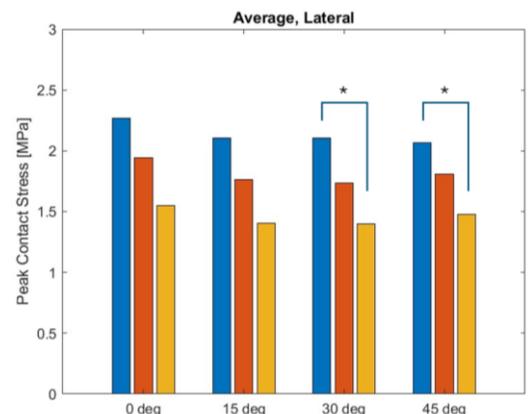
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**Table 1:** Average change in WCoC from the intact condition. Positive values (green) denote anterior change, negative values (red) denote posterior change.

	Knee Flexion Angle	Compartment	
		Medial (mm)	Lateral (mm)
		Average	Average
Increased PTS (Anterior Opening Wedge Osteotomy)	0°	-1.3	-1.7
	15°	-1.4	-3.5
	30°	-1.3	-3.2
	45°	-1.1	-2.6
Decreased PTS (Anterior Closing Wedge Osteotomy)	0°	-1.4	3.7
	15°	-1.7	4.7
	30°	-1.9	4.4
	45°	-2.1	3.7



**Figure 1:** Tekscan images of a representative knee to highlight the change in position of the weighted center of contact.



**Figure 2:** Average peak contact stress for each condition in the lateral tibial compartment at 30° flexion. The star denotes statistically significant difference.