

Leveraging Intra-Operative Knee Joint Laxity Characterization to Develop Surgeon-specific Predictive Models of Tibial Insert Thickness

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Disclosures: P. Chinimilli: 3A; Exactech. 4; Exactech. W. Fan: 3B; Exactech. L.D. Angibaud: 3A; Exactech. 4; Exactech. A. Jung: 3A; Blue-Ortho. 4; Exactech. J. Huddleston: 3B; Exactech.

INTRODUCTION: Total knee arthroplasty (TKA) represents the gold standard in alleviating pain and improving function for patients with end-stage knee osteoarthritis. However, nearly 20% of TKA patients report some level of post-operative dissatisfaction. Soft tissue balancing plays an important role in post-operative clinical outcomes. One of the factors that contributes to the soft tissue management relates to the proper selection of tibial insert thickness, an intraoperative surgical decision that varies based on surgeon experience and preference. This study aims to 1) examine the correlation between acquired laxity curves and chosen tibial insert thickness; 2) build surgeon-specific predictive models recommending tibial insert thickness based on the laxity curves.

METHODS: The study utilized anonymized database associated with an instrumented computer-assisted surgery (CAS) system. Surgeons with over 30 cases of tibia first technique were retrospectively included, without any exclusions. During trial reduction, a trial femoral component was impacted onto the prepared distal femur and a mechanical intra-articular tibial distractor was introduced into the joint space which applied a quasi-constant distraction force once released, regardless of the joint gap, between the proximal tibial cut and the trial femoral component. Then, the limb was manually taken through a full arc of motion and corresponding joint laxities were recorded by the CAS system. Medial and lateral (ML) gaps were measured at 0° to 120° of flexion with 5° to 15° increments. Surgeon-specific correlations between ML gaps and selected tibial insert thickness were assessed via Pearson (r) and Spearman (p) correlation coefficients for each available flexion angle. The data linked to the flexion angle that yielded highest correlation were selected to train the predictive models. For each surgeon, the data was split into a train-test ratio of 2:1. Random Forest (RF) and Ordinal Logistic Regression (OLR) models were trained, and the accuracy was evaluated by calculating proportions of exact predictions, predictions within 1mm, and predictions within 2mm using testing datasets.

RESULTS SECTION: Among a total of 1155 cases, 8 surgeons associated with a total of 625 cases were selected for the correlation analysis. All surgeons exhibited correlation ($r > 0.35$ and $p > 0.3$) between ML gaps and tibial insert thickness except for surgeon 2, displayed in Figure 1. Notably, a relatively stronger correlation was observed between medial gaps and tibial insert thickness when compared to lateral gaps. Table 1 illustrates the predictive accuracy for three cases per surgeon using RF and OLR models. In summary, OLR model outperformed RF model in terms of mean exact prediction accuracy (52.9% vs 45.7%), mean prediction accuracy within 1mm difference (68.6% vs 63.3%), and mean prediction accuracy within 2mm difference (93.1% vs 92.2%).

DISCUSSION: This study first investigated the correlation between knee joint laxity acquired during the trial reduction and the selected thickness of the implanted tibial insert in TKA with the tibial-first technique. The findings demonstrated that the relationship between these two parameters tended to be surgeon specific. The predictive models performed reasonably accurately with a high correlation observed between joint gaps and tibial insert thickness. The sample size is one of the limitations of this study which can impact the model training and testing. Further investigations of other potential predictors of tibial insert thickness will be performed to improve the performance of predictive models.

SIGNIFICANCE/CLINICAL RELEVANCE: This study's surgeon-specific predictive models for tibial insert thickness selection offer substantial potential to enhance surgical decision making and ensure post-operative joint stability in TKA procedures. Moreover, these models have the potential to streamline the selection of the tibial insert thickness, potentially replacing the conventional method of trailing different thickness options.

IMAGES AND TABLES:

Figure 1: correlation between tibial insert thickness and ML gaps for 8 surgeons

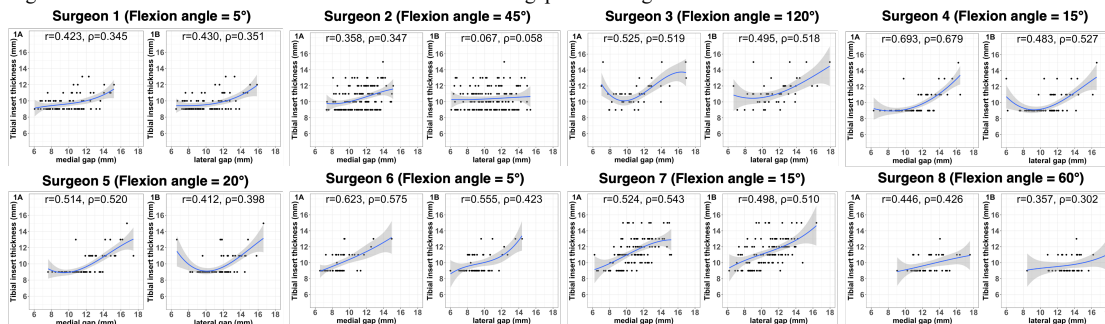


Table 1: Predictive models accuracy summary for 8 surgeons on the test datasets. M: train size and N: test size.

Surgeon 1: M=54, N=28				Surgeon 5: M=46, N=20			
	exact	≤ 1mm diff	≤ 2mm diff		exact	≤ 1mm diff	≤ 2mm diff
Random Forest (N%)	16 (57.1%)	25 (89.3%)	27 (96.4%)	Random Forest (N%)	11 (55%)	20 (100%)	20 (100%)
Ordinal Logistic Regression (N%)	15 (53.6%)	23 (82.1%)	27 (96.4%)	Ordinal Logistic Regression (N%)	11 (55%)	20 (100%)	20 (100%)
Surgeon 2: M=103, N=52				Surgeon 6: M=37, N=19			
	exact	≤ 1mm diff	≤ 2mm diff		exact	≤ 1mm diff	≤ 2mm diff
Random Forest (N%)	14 (26.9%)	31 (59.6%)	41 (78.8%)	Random Forest (N%)	11 (57.9%)	12 (63.2%)	18 (94.7%)
Ordinal Logistic Regression (N%)	26 (50%)	37 (71.2%)	45 (86.5%)	Ordinal Logistic Regression (N%)	14 (73.7%)	15 (78.9%)	18 (94.7%)
Surgeon 3: M=30, N=15				Surgeon 7: M=77, N=39			
	exact	≤ 1mm diff	≤ 2mm diff		exact	≤ 1mm diff	≤ 2mm diff
Random Forest (N%)	4 (26.7%)	10 (66.7%)	14 (93.3%)	Random Forest (N%)	10 (25.6%)	22 (56.4%)	29 (74.4%)
Ordinal Logistic Regression (N%)	6 (40%)	12 (80%)	13 (86.7%)	Ordinal Logistic Regression (N%)	9 (23.1%)	21 (53.9%)	33 (84.6%)
Surgeon 4: M=45, N=23				Surgeon 8: M=28, N=15			
	exact	≤ 1mm diff	≤ 2mm diff		exact	≤ 1mm diff	≤ 2mm diff
Random Forest (N%)	13 (56.5%)	13 (56.5%)	23 (100%)	Random Forest (N%)	9 (60%)	9 (60%)	15 (100%)
Ordinal Logistic Regression (N%)	14 (60.9%)	14 (60.9%)	22 (95.7%)	Ordinal Logistic Regression (N%)	10 (66.7%)	10 (66.7%)	15 (100%)
Summary for 8 Surgeons				Summary for 8 Surgeons			
	exact	≤ 1mm diff	≤ 2mm diff		exact	≤ 1mm diff	≤ 2mm diff
Random Forest (mean ± std N%)	45.7% ± 14.1%	63.3% ± 11.2%	92.2% ± 10%	Random Forest (mean ± std N%)	45.7% ± 14.1%	63.3% ± 11.2%	92.2% ± 10%
Ordinal Logistic Regression (mean ± std N%)	52.9% ± 15.8%	68.6% ± 11.3%	93.1% ± 6.2%	Ordinal Logistic Regression (mean ± std N%)	52.9% ± 15.8%	68.6% ± 11.3%	93.1% ± 6.2%