INTRODUCTION
Olecranon fractures are the second most common osseous injury of the elbow.1 The majority are displaced fractures that can be successfully treated with open reduction and internal fixation.2 However, with severe comminution or significant bone loss such as in open fractures, excision of the comminuted fragments and repair of the triceps to the ulna is recommended.2,3 The triceps can be reattached to either the anterior or posterior aspect of the ulna.4,5 The purpose of this study was to determine the effect of triceps repair technique on elbow laxity and extension strength in the setting of olecranon deficiency using a cadaveric model.

METHODS
Eight fresh frozen cadaveric arms amputated at midhumerus were used (age 75 ± 11 years). 3D surface models were generated from CT imaging and a pre-op plan determined cutting planes corresponding to sequential levels of olecranon resection. The cutting planes divided the olecranon into 25% increments. Olecranon resections of 0% and 100% were defined at the most proximal and distal aspects (respectively) of the greater sigmoid notch. The pre-op plan was registered to the specimen anatomy using an Iterative Closest Point algorithm, providing real-time 3D navigation of the olecranon resection. Muscle tendons (triceps, brachialis, brachioradialis and triceps) were sutured to the actuators of an elbow motion simulator, which produced active elbow extension by applying physiologic loads to the tendons. Steinmann pins secured the forearm in neutral rotation and the wrist in neutral flexion.

Passive elbow extension was performed by manually moving the arm. An electromagnetic tracking system (Flock Of Birds®) recorded active and passive kinematics with the arm in the varus and valgus orientations. Using a 0.4 mm oscillating saw, serial resections of the olecranon were performed at 25% increments using the aforementioned image guidance. A triceps advancement was repaired using either an anterior or posterior repair to the remaining olecranon. The triceps sutures were passed through two transosseous tunnels adjacent to the articular surface (anterior repair) or adjacent to the subcutaneous border of the ulna (posterior repair). The free suture ends were clamped to allow for repeated testing without the need to resuture the tendon for each resection. The order of the repairs was randomized. We quantified extension strength in the dependent position with the elbow at 90° of flexion using a force transducer located at the distal ulnar styloid. The motion simulator was used to increase triceps tension from 25 to 200 N of static load while the transducer recorded the reaction force. This was termed “triceps extension strength”. This protocol was performed in the intact elbow and repeated at all stages of olecranon resections. Outcome variables included maximum varus-valgus elbow laxity and triceps extension strength. Two-way repeated measures ANOVAs were performed for laxity comparing resection level and repair method. Three-way repeated measures ANOVAs were performed for triceps extension strength comparing triceps tension, resection level and repair method. Significance was set at p < 0.05.

RESULTS
Progressive sectioning of the olecranon increased elbow laxity in both active and passive extension modes (Fig. 1) (p < 0.001). Although the posterior repair produced greater laxity for all but the 50% resection, this difference was not significant in either active (p = 0.2) or passive (p = 0.1) extension. Active extension produced less joint laxity than passive extension throughout elbow extension. This was true for both the anterior (p = 0.007) and posterior repairs (p = 0.001). The posterior repair provided greater extension strength than the anterior repair at all applied triceps tensions and for all olecranon resections (Fig. 2) (p = 0.01). Initial resection from the intact state reduced extension strength for both repairs (p < 0.01), though there was no effect of progressive olecranon resections (p = 0.09).

DISCUSSION
Laxity was greater for passive compared to active motion suggesting that post-surgical therapy should employ active motion to optimize joint tracking and avoid undue stress on the collateral ligaments. There was no difference in laxity between the anterior and posterior triceps repairs. At most, the posterior repair produced 3° more laxity than anterior for the 100% resection. Thus, even for large olecranon fractures, the choice of triceps repair may not have significant impact on joint stability. Triceps extension strength was higher for the posterior repair as has previously been reported by DiDonna and coworkers.5 This is likely due to the greater distance of the posterior repair to the joint rotation center, thus providing a greater moment arm for increased mechanical advantage of the triceps. Extension strength was not reduced by progressive olecranon resections, though there was a reduction from the intact state, at least with the elbow at 90°. The lack of an effect of progressive resections on extension strength may be due to wrapping of the triceps tendon around the trochea resulting in the tendon having a final “angle of attack” that is more in line with the ulna. Thus, loss of the olecranon in the distal axial direction would have little impact on the effective moment arm, at least with the elbow at 90°. Conversely, the difference in location of the anterior versus posterior repairs is in a perpendicular direction. The anterior repair brings the triceps insertion much closer to the joint rotation center, thus reducing the moment arm. Since there was no significant difference in laxity between the repairs, the authors favour the posterior repair due to its significantly higher triceps extension strength.

REFERENCES

The Effect of Triceps Repair Technique Following Olecranon Excision on Elbow Laxity and Extension Strength: An In-Vitro Biomechanical Study

+1Ferreira, L M; 2Bell, T H; 3Johnson, J A; 4King, G J W
+1Department of Biomedical Engineering, The University of Western Ontario, London, ON; 2The Hand and Upper Limb Centre, St Joseph’s Health Care, London, ON

ggking@uwo.ca

Figure 1: Elbow joint laxity for the anterior and posterior triceps repairs using active and passive elbow extension in the intact state and all levels of olecranon resection. Laxity increased with progressive resections (p < 0.001). Laxity was greater for passive than active extension (p < 0.01).

Figure 2: Extension strength vs triceps muscle tension. Posterior repair resulted in greater extension strength than anterior repair (p = 0.01).