INTRODUCTION
Rotator cuff injuries are common, with approximately 400,000 cuff repairs performed each year in the United States alone. Surgical repair of torn cuff tendons involves reattachment of the torn end of the tendon to the original footprint on the proximal humerus, typically using suture anchors. In recent years, suture anchors have evolved into knotless systems, which are designed to facilitate arthroscopic cuff repair through enhanced suture management and the ability to achieve fixation without the need to tie knots. While the repair procedure has been simplified by these novel anchor designs, cuff repairs still exhibit a high incidence of inadequate healing and formation of gaps at the repair site, and healing of the cuff tendons to bone remains to be a significant clinical challenge. One crucial aspect to promoting healing is minimizing gap formation that may occur due to suture slippage with knotless anchor designs or anchor loosening, and therefore it is important to understand the cyclic performance of the suture anchors used for the repair. The objective of this study was to compare the fixation strength of different knotless suture anchor designs under cyclic loading, as well as the ultimate fixation strength.

METHODS
Materials: PEEK knotless suture anchors were tested, including the ALLthread 5.5 Knotless (Biomet), Footprint PK 5.5 (Smith & Nephew), Opus Magnum PI (ArthroCare), PopLok 4.5 (ConMed Linvatec), ReelX STT (Stryker Joint Preservation), and VersaLok (DePuy Mitek, Fig 1). Anchors (n=6) were inserted into 12.5 pcf cellular polyurethane foam with a 20 pcf cortical shell (3 mm) with each manufacturer’s high strength suture loaded at 10 lb of tension.

Mechanical Testing: Foam blocks were mounted to a materials testing system (MTS 858 Mini Bionix) with a 15 cm circumference suture loop loaded at a 70º angle to mimic the direction of tendon loading (Fig 2). A 45 N pre-load was applied at 10 N/sec and held for 20 seconds, followed by cyclic loading from 10 N to 45 N at 0.5 Hz to a maximum of 500 cycles. Anchors that withstood cyclic loading were subsequently loaded to failure (suture slippage or breakage) at 0.5 mm/sec. The maximum increase in suture displacement after the first 100 cycles was recorded for 101-200, 201-300, 301-400, and 401-500 cycles. In addition, the amount of force required to reach 3 mm of total displacement, which has been suggested to indicate clinical failure, and the maximum loading force were determined.

Statistical Analysis: For each parameter, means and standard deviations were calculated for each group. A one-way ANOVA was performed to determine the effect of anchor type on each parameter (p≤0.05). Tukey HSD post-hoc tests were subsequently performed for pair-wise comparisons (SYSTAT 12).

RESULTS
Mean displacements during cyclic loading were less than 3 mm (clinical failure limit) for all anchors (Fig 3), with the exception of two Footprint PK samples that failed during the first 100 cycles. The ReelX STT anchor exhibited significantly greater mean load at 3 mm of displacement compared to all anchors (p=0.02) except the VersaLok (p=0.158, Fig 4). When loaded until failure, the ReelX STT anchor exhibited significantly greater fixation strengths compared to all other anchors tested (p<0.0001), and the ultimate load for the VersaLok was greater than all anchors except the ReelX STT (p=0.0001, Fig 5).

DISCUSSION
The goal of this study was to compare the fixation strength of the latest generation of commercially available knotless suture anchors designed for rotator cuff repair. The results presented here indicate that, in general, all anchor types tested exhibit displacements during cyclic loading of less than 3 mm, which has been suggested to be the lower displacement limit above which clinical failure may occur. However, two of the Footprint PK anchors failed by suture slippage early during cyclic testing, suggesting that these anchors may not grip the suture as securely as the other anchor types. In addition, the ReelX STT exhibited statistically greater loads at 3 mm of displacement compared to four of the five other anchors tested, as well as the greatest ultimate load in this testing series, suggesting that this anchor type may provide the highest fixation strength compared to the other anchors in this foam model. A polyurethane foam model was chosen in order to provide a consistent testing medium for a more systematic comparison compared to animal or human bone, while it is recognized that the values reported here may not be representative of all clinical scenarios due to potentially large patient-to-patient variations in bone quality.

REFERENCES