INTRODUCTION:
Recently, the Remplissage procedure, which involves inserting the infraspinatus tendon and posterior joint capsule into an engaging Hill-Sachs lesion has begun to gain popularity. Due to the relative infancy of this technique, a standardized procedure for suture anchor and suture placement has not been defined. Therefore, the purpose of this biomechanical study was to compare three Remplissage techniques by evaluating their effects on joint stiffness and motion.

METHODS:
Cadaveric forequarters (n=7, average age=71) were mounted on a custom active biomechanical shoulder simulator capable of loading the infraspinatus & teres minor, subscapularis, supraspinatus, and the three deltoid heads (Figure 1). The Remplissage techniques were implemented for 15 and 30% Hill-Sachs lesions with one and two anchors placed, respectively. Three randomly ordered Remplissage techniques were conducted: T1 - anchor(s) in the valley of the defect, T2 - anchor(s) in the rim of the humeral head; T3 - anchor(s) in the valley with medial suture placement. Passive ROM and shoulder stability were evaluated using a repeated measures design with the states of: intact, Bankart lesion and repair, 15 and 30% humeral head defects, and T1, T2, and T3 Remplissage techniques. Outcomes were assessed in adduction and 90° combined abduction. Combined shoulder abduction was achieved using a glenohumeral-scaphulothoracic rhythm of 2:1. Outcome variables included stiffness, and internal/external (IE) rotational range of motion (ROM). Joint stiffness was tested in neutral and 60° of external humeral rotation using an anteriorly direct load up to 80N. Humeral IE rotation ROM was determined using a predefined clinically relevant applied torque. Data were normalized to intact in order to facilitate comparison between Remplissage techniques and tested using One-Way ANOVAs with significance set to p<0.05.

RESULTS:
Techniques 1, 2 and 3 were all found to greatly increase joint stiffness, from 100 to 320% compared to the unrepaired 15 and 30% Hill-Sachs lesions; however, only comparisons at the 30% lesion level were found to be statistically significant (T2: 1.46±0.98, p=0.047, T3: 2.36±0.87, p=0.002). Despite the large range of increase in stiffness, no technique stiffened the joint significantly more than the others (0.3772±1.000).

In abduction, significant reductions in IE ROM were observed between the T1 and T3 Remplissage techniques and the unrepaired 15% Hill-Sachs lesion (T1: 0.17±0.11, p=0.039, T3: 0.27±0.16, p=0.024); however, no technique resulted in a significantly different ROM compared to the other techniques (Figure 2). For 30% defects, all techniques produced reductions in IE ROM compared to the unrepaired state (T1:0.24±0.10, p=0.005; T2: 0.34±0.14, p=0.004; T3: 0.43±0.24, p=0.018). In adduction, for the 15% defect, T2 did not cause a significant reduction; however, T1 and T3 reached a significant difference to the unrepaired state (T1: 0.33±0.21, p=0.035; T3: 0.46±0.24, p=0.015), while at 30%, all techniques significantly restricted motion (p<0.029). Additionally, T3 approached a significant reduction compared to T1 (0.34±0.12, p=0.087).

DISCUSSION:
The Remplissage procedure has recently been promoted as a method for the treatment of engaging Hill-Sachs lesions. This procedure utilizes the infraspinatus tendon and posterior capsule to convert the intra-articular lesion into an extra-articular one by inserting the soft tissues in to the defect by way of suture anchors. However, the precise suture anchor and suture placement technique which provides the best outcomes has yet to be described as no in-vitro investigations or large scale trials have been undertaken. 

The current study found that all evaluated Remplissage techniques resulted in a large joint stiffening effect in the anterior direction, with increases ranging from 100 to 320% that of the unrepaired Hill-Sachs lesion; however, only T2 and T3, when applied to a 30% Hill-Sachs lesion, resulted in statistically significant increases. Additionally, no technique differed significantly from the others on the basis of stiffness. This finding of relatively few significant increases in stiffness despite the large increase in stiffness observed for each technique indicates that the ability to consistently tension the sutures plays an important role in the Remplissage’s effect on joint stability.

The Remplissage procedure was found to have statistically significant restrictive effects on IE rotation ROM at both levels of Hill-Sachs lesion. Specifically, techniques one and three significantly restricted motion in both adduction and abduction when compared to the unrepaired 15 and 30% lesions, while T2 only did so at 30%. Conversely, no differences were observed between Remplissage techniques at any position and lesion size combination except in the case of 30% T3 which approached a significant restriction in motion compared to T1 in adduction. It should again be noted that large standard deviations prevented some T2 comparisons from being significant despite restricting motion more than other significant T1 comparisons. Nonetheless, it can still be concluded that Remplissage reduces motion and to a significant degree in many cases, even when treating 15% lesions which require minimal soft tissue inserting.

By considering the stiffening effects and restrictions to motion we can say that all Remplissage techniques effectively increase stiffness but concurrently restrict motion and are susceptible to large variation in their effect due to the technical challenges of consistently tying the sutures. Therefore, this study has determine that Remplissage technique does have a significant effect on joint biomechanics, and that while suture tensioning is highly variable in each technique, the T1 repair is least affected by this issue and consistently causes the least motion restriction.

SIGNIFICANCE:
These findings are significant as they have, for the first time, elucidated the effects of three Remplissage techniques. This information will help to guide clinical practice; specifically, providing objective results regarding the effects each technique has on joint stiffness and range of motion.