INTRODUCTION
Currently, scaffolds derived from natural and synthetic biomaterials are being marketed as augmentation devices for rotator cuff repair. However, only a few studies have demonstrated the potential of scaffold augmentation to improve the initial biomechanical properties of a rotator cuff repair construct. Further, the appropriate scaffold material properties and/or surgical application techniques for achieving optimal biomechanical performance in the setting of rotator cuff repairs are unknown, as is the percent load carried by a scaffold when used for rotator cuff repair augmentation. To address these questions and enhance our understanding of the basic mechanics of scaffold augmentation, we recently developed and validated an analytical model for non-augmented and augmented human rotator cuff repairs. The objectives of the current study are now to use this model to predict: (1) the manner in which simulated changes to components of the tendon repair, such as reduced tendon quality, altered surgical technique and different scaffold designs, influence the biomechanical performance (yield load and stiffness) of the repair construct and (2) the percent load carried by the scaffold augmentation component of the repair construct in each of these simulated clinical scenarios.

MATERIALS AND METHODS
Previously, we developed and validated an analytical model for simplified non-augmented and augmented human rotator cuff repairs, based on the physics of springs in series and in parallel. Briefly, the non-augmented repair was modeled as two springs in series (Fig 1A, 1B), while the augmented repair was modeled as a combination of five springs in series and parallel (Fig 1C, 1D). The individual spring components, representing the points of compliance of the repair constructs, were modeled as non-linear springs (Eq 1 and 2).

\[ F = F_o + A x^b \] \hspace{0.5cm} \text{(1)}
\[ F = F_o^a + A x^b \] \hspace{0.5cm} \text{(2)}

The parameters \( F_o, A, b, \) and \( c \) were estimated using non-linear least-squares analysis of experimental data from each individual component. The parameter \( A \) represents a proportionality constant associated with changes in load-displacement characteristics of a given spring component. Hence, in the current study parameter \( A \) was varied parametrically to simulate clinically relevant scenarios, namely, changes in tendon quality, altered surgical technique(s) and different scaffold designs (Table I). The biomechanical performance of the repair constructs, i.e., the yield load and stiffness, and the percent load carried by the scaffold augmentation component, were evaluated for each of the parametrically simulated conditions.

RESULTS
The model predictions for the simulated clinical scenarios are shown in Figures 2-4 and summarized numerically in Table I.

DISCUSSION
The model predicts that the biomechanical performance of a rotator cuff repair at the time of surgery can be modestly increased by augmenting the repair with a scaffold which has tendon-like properties. However, engineering a scaffold with supra-physiologic stiffness will not translate into yet stiffer or stronger repairs. Importantly, the mechanical properties of a repair construct are most influenced by the properties of the tendon-to-bone repair. In the clinical setting of a weak tendon-to-bone repair, scaffold augmentation will significantly off-load the repair and largely mitigate the poor construct properties, based on model predictions. Future efforts in the field of rotator cuff repair should be directed toward strategies that strengthen the tendon-to-bone repair and/or towards engineering scaffolds with tendon-like mechanical properties that also promote rapid or effective biologic healing.

REFERENCES

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