INTRODUCTION

Reverse total shoulder arthroplasty (RTSA) is commonly used in patients with cuff tear arthropathy (CTA) to relief pain and to restore active humeral elevation ROM [1]. The reverse prosthetic designs medialise the humeral centre of rotation increasing the Deltoid moment arm and its performance [2]. However, clinical studies have shown that patients with RTSA usually show poor humeral internal/external ROM [1]. Especially in the case of atrophy or fatty infiltration of the posterosuperior part of the RC, involving both infraspinatus and teres minor (TM), the RTSA fails to restore active external rotation [3]. Latissimus dorsi (LD) tendon transfer has been proposed as a solution to restore active external rotation in patients with massive and irreparable rotator cuff (RC) tears [4].

There are only few studies investigating the biomechanics of LD transfer in RTSA and concentrate mostly on analyzing moment arm changes. The aim of the this investigation is to present an in depth biomechanical analysis of the LD transfer in RTSA, looking at moment arms (MA), muscle forces as well as joint contact loading in a variety of kinematic activities.

METHODS

An established shoulder biomechanical model, the Newcastle Shoulder Model (NSM) [5], was used to investigate the biomechanical properties of the LD transfer in RTSA. The model was adapted according to the techniques of Kontaxis et al., [2] that describes the geometry of a commercial reverse prosthesis (DELTAS III®, DePuy). The model consists of six rigid bone segments (thorax, clavicle, scapula, humerus, radius and ulna), four joints and includes 31 muscles that are divided into a total of 90 lines of action that are modeled as elastic strings. The strings wrap around simple geometric shapes (e.g spheres and cylinders) that describe the bony geometry. The LD was modeled with 5 strings. The model can calculate muscle moment arms for a given motion and predict muscle and joint contact forces using inverse dynamic techniques.

Figure 1: The NSM was adapted in order to simulate a RTSA with and without a LD transfer

Model set-up and kinematic inputs

Two different model set-ups were used: i) RTSA without LD transfer (anatomical attachment) ii) RTSA with LD transfer, where the attachment site of the LD were located at the posterolateral site of the humeral diaphysis, as it was described by Favre et al. [6]. During all simulations in both models, all the RC muscles (including the teres minor) were set inactive.

A set of kinematic tasks were used as an input to the model: i) Abduction 0-150 deg, ii) Forward Flexion 0-150 deg. iii) Int/External rotation in 90 deg of abduction, and iv) Simulation of an overhead Activity of Daily Living (ADL-Lift block to overhead shelf) as used by other upper extremity kinematic studies.
Outcomes variables
Muscle moment arms (MA), forces and glenoid joint loading were calculated for all tasks on both model set-ups. Rotational MA were evaluated for the external-internal task, while adduction MA was measured during abduction and forward flexion. The negative sign on the rotational angles and MA indicate external rotation and vice versa.

RESULTS AND DISCUSSION
The MA results confirmed the ability of LD to externally rotate the arm after the tendon transfer. Comparing the MA values in the Int/Ext task, the model predicted a similar trend with the cadaveric study of Favre et al., even if the latter predicted much larger rotational MA for the LD (Fig 2). The adductive MA values were also increased for all the tasks (Abduction, Forward Flexion, ADL) but the differences were small (8.3% - 11.4%).

LD rotational moment arm in Humeral int/ext rotation

The change of MA had also an effect on the prediction of muscle and joint contact loads. The model predicted a much lower glenoid loading for the demanding task of ADL. The total load magnitude was reduced by 31%, while the biggest decrease was on the superior glenoid load (Fig. 3).

The high loading values on the model with the anatomical LD can be explained by the lack of the necessary muscles that generate external moment during the task. As a result the model has to activate excessively the posterior deltoid in order to achieve equilibrium and as a result increase the superior loading. The LD transfer model was able to generate the necessary external moment with a small activation of the LD, releasing the deltoïd tensioning and thus the superior loading.

CONCLUSIONS
The results of the study indicate that LD transfer on RTSA can benefit the external rotation and loading of the glenoid when there is a full thickness RC tear with a weak (or lack) Teres minor. This is an ongoing investigation where multiple LD transfer attachment sites will be investigated together with a more comprehensive set of kinematic activities. The study aims to inform clinicians and orthopaedic manufacturers on how to optimize RTSA and improve functional outcomes in patients with CTA.

REFERENCES