Appendix

Experimental Setup

Following resection of the humerus at the midpart of the shaft, an intramedullary humeral rod, instrumented with a six-degrees-of-freedom load cell (Mini45; ATI Industrial Automation, Apex, North Carolina) and optical trackers (Optotrak Certus; NDI, Waterloo, Ontario, Canada), was cemented into the humeral shaft, while the distal portion was left free to mate with the simulator. To provide a reference for rotation, a transverse axis on the humeral rod was aligned with the anatomic transepicondylar axis of the elbow on the basis of the relationship between the transepicondylar axis and the biceps groove at the level of the surgical neck as described by Balg et al.[23].

Humeral and scapular digitizations were obtained with respect to the bone-affixed optical markers to create an International Society of Biomechanics (ISB) Euler rotation sequence[24]. The functional glenohumeral joint center was determined from kinematic recordings with use of Woltring's algorithm[25-27]. The scapula was then cemented to the simulator in 10° of forward inclination as measured between the superior axis of the ISB scapular coordinate system and the vertical surface of the simulator's main plate. On the basis of the literature, 10° of anterior tilt was determined to be the average value of scapular tilt with the arm in adduction, and this was maintained during testing in abduction as the literature also indicates that scapular tilt is minimal up to 90° of humerothoracic rotation[28,29]. Following testing of the intact specimen, digitizations at the superior, inferior, anterior, and posterior aspects of the glenoid rim were recorded and were used to create a separate glenoid coordinate system coincident with the intact glenohumeral joint center. This coordinate system was used in post-hoc analyses to determine glenohumeral joint translations.

The simulator achieved highly repeatable joint configurations without affecting the true unconstrained motion of the natural glenohumeral joint[7,14,15,30,31] (Fig. 2) by positioning the humeral rod with use of a spherical bearing that allowed free glenohumeral translation and rotation. Nine muscle groups were loaded along physiologically accurate lines of action with use of a low-friction guide system and low-friction computer controlled pneumatic actuators (Airpel E16; Airpot, Norwalk, Connecticut). The sutures of each muscle group were loaded as follows: the supraspinatus, infraspinatus and teres minor, and subscapularis (7.5 N); the long head of the biceps and the conjoint tendon (10 N); and the anterior, middle, and posterior deltoid heads (5 N)[6,7,14,30,31]. The ratios between these loads and their specific magnitudes were drawn from previous studies in which similar protocols had been utilized[6,7,14,30,31] as well as studies that investigated the effect of joint load magnitude on glenohumeral joint stability[32]. Abduction, composed of glenohumeral and scapulothoracic rotation, was achieved with use of a 2:1 ratio as described by McQuade and Smidt[33].

Real-time feedback of the load applied to the glenohumeral joint was achieved with use of a uniaxial load cell (model 34; Honeywell, Golden Valley, Minnesota) while glenohumeral kinematics and forces were monitored during testing with use of the optical tracking markers and intramedullary load cell described above.

Statistical Analyses

Two-way repeated-measures analysis of variance (ANOVA) was performed for each outcome variable to assess the main effects and any interaction effects of the repair technique (Bristow versus Latarjet) across the three glenoid-defect levels (0%, 15%, and 30%). In the case of any interactions, follow-up post-hoc tests were performed. The results from testing of the intact specimens could not be included in the two-way ANOVA as they were not repeated measurements; thus, a series of one-way repeated-measures ANOVAs were performed in order to allow comparisons between the reconstructions and the intact state. These one-way repeated-measures ANOVAs and associated pairwise comparisons were carried out for all outcome variables at each tested shoulder configuration and defect level. Each analysis consisted of three conditions: intact, after the Bristow procedure, and after the Latarjet procedure. Significance was set to $p < 0.05$. A priori power analyses were performed for each outcome variable. It was found that eight specimens were sufficient to achieve a minimum power of 80% for detecting clinically relevant differences of approximately 10° for range of motion and 30% for joint stiffness. ■