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Proximal versus distal screw placement for biceps tenodesis: a biomechanical study

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ABSTRACT

Purpose. To assess the maximum and end torque of a fourth-generation composite humerus model with no screw inserted or with a screw inserted in the distal (subpectoral) position or proximal (suprapectoral) position.
Methods. 24 large-size, fourth-generation composite humeri were randomised to the control (n=8), proximal (n=8), or distal (n=8) group. For the latter 2 groups, an 8-mm-head interference screw (7x25 mm) was inserted at 1 cm proximal and 1 cm distal to the superior aspect of the insertion of the pectoralis major tendon, respectively. The maximum and end torque of each humerus was assessed.
Results. Respectively for the control, proximal, and distal groups, the maximum torque was 81.8, 78.7, and 74.3 Nm, and the end torque was 80.7, 78.6, and 71.8 Nm; only the difference between control and distal groups was significant (p=0.005 for maximum torque and p=0.033 for end torque). All fractures in both control and proximal groups involved the distal 1/3 humerus. In the distal group, the fractures involved either the distal 1/3 humerus (n=6) or the screw-hole (n=2); the difference between the 2 types of fracture was not significant in terms of maximum torque (75.7 vs. 70.0, p=0.086) or end torque (75.3 vs. 61.4, p=0.40).
Conclusion. Compared with proximal placement of an interference screw, distal placement decreased the maximum torque (though not significantly) and may increase the risk of proximal humeral fracture.

Key words: *humerus; tenodesis; torque*

INTRODUCTION

Pathology of the long head of biceps brachii and its pulley system is a major cause of shoulder pain.[1–7] Tenosynovitis, subluxation, dislocation, partial tears, and superior labral tear from anterior to posterior are some of the causes.[1,5,8,9] Treatment for biceps tendon injuries includes conservative and operative methods.[2,3,5,9] Operative treatment consists of biceps tenotomy or tenodesis,[1,6,8,9] with tenodesis more

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Table 1
Case reports of periprosthetic proximal humeral fracture involving the screw hole

Study	Sex/ age (years)	Side	Tenodesis location	Screw used	Fracture location and type	Time from tenodesis to fracture (months)	Activity during fracture
Dein et al.,[9] 2014	M/46	Right	Subpectoral biceps tenodesis	8 mm, bioabsorbable	Proximal 1/3 spiral fracture, entering the screw hole	10	Pitching a baseball
Sears et al.,[7] 2011	M/47	Left	Subpectoral biceps tenodesis	8 mm, bioabsorbable	Proximal 1/3 spiral fracture, through the screw hole	6	Fall
Sears et al.,[7] 2011	M/34	Right	Subpectoral biceps tenodesis	Bioabsorbable	Proximal 1/3 short oblique fracture, through the screw hole	4	Picking up a bag

frequently used in younger, more active patients. Techniques for biceps tenodesis include suturing the tendon to the rotator cuff tendons, placing the tendon into a pre-drilled keyhole in the proximal humerus, using suture anchors to suture the tendon to bone, and securing the tendon to the bone using an interference screw.[3,4,7,9] The latter is relatively simple, preserves the muscle tendon, soft tissues, and the length-tension relationship, debulks the tenosynovitic biceps from the bicipital groove and glenohumeral joint, and is biomechanically strong.[2–4,6,7,10,11] The technique has a low incidence (2%) of complications; most of which are related to fixation failure and postoperative pain,[5,7,10,11] with no proximal humeral fracture.[5,10,11] Nonetheless, 3 cases of periprosthetic proximal humeral fractures involving the drill hole have been reported (Table 1).[9,7] The drill hole size, depth, and location can create a stress riser.[7] This study aimed to assess the maximum and end torque of a fourth-generation composite humerus model with no screw inserted or with a screw inserted in the distal (subpectoral) position or proximal (suprapectoral) position. It was hypothsised that distal screw placement decreased the torque and thus increased the risk of fracture.

MATERIALS AND METHODS

24 large-size, fourth-generation composite humeri[12,13] (model #3404; Pacific Research Laboratories, Vashon [WA], USA) were used. The composite humerus accurately reproduces the biomechanical properties of human bone for assessing bending, axial, and torsional loads,[12–14] and has been validated for clinical research, because it reduces inter-specimen variability compared with cadaveric bone.[14]

The humeri were randomised to the control (n=8), proximal (n=8), or distal (n=8) group (Fig. 1). For the latter 2 groups, an 8-mm-head interference screw (7x25 mm) [Smith & Nephew] was inserted in a concentric unicortical manner by a single surgeon. According to the insertional footprint anatomy of the pectoralis major tendon,[15] the proximal and distal screws were respectively inserted at 1 cm proximal and 1 cm distal to the superior aspect of the insertion

Figure 1 Fourth-generation composite humerus model with no screw inserted or with a screw inserted in the distal (subpectoral) position or proximal (suprapectoral) position.

Figure 2 A composite humerus is fixed in a modified lathe for assessing maximum and end torque.

Table 2
Maximum and end torque of the composite humerus with or without insertion of a screw

Screw placement	Mean±SD torque (Nm)	
	Maximum	End
Control (n=8)	81.8±5.1	80.7±5.9
Proximal (n=8)	78.7±6.0	78.6±6.0
Distal (n=8)	74.3±3.6	71.8±8.6
Fracture involving the distal 1/3 humerus (n=6)	75.7±2.7	75.3±2.5
Fracture involving the screw-hole (n=2)	70.0±2.0	61.4±14.2

of the pectoralis major tendon, which was determined to be 42.2±8.5 mm from the superomedial corner of the greater tuberosity, referencing off the lateral lip of the bicipital groove.[15]

A testing module that replicates internal rotation proximally and external rotation distally on the humerus was designed to eliminate a flexion/bending force as a confounding factor.[16] A modified lathe (Easson ES-8) with 4-point fixation (each with 6 Nm of torque applied) proximally and distally was used to prevent slippage (Fig. 2). The longitudinal axis of the humeral diaphysis was aligned to that of the actuators to ensure consistent and replicable outcome. The humerus was loaded with a 150 Nm compression force, and then a torsional force was applied. The torque was recorded using iDAS 80 at one second intervals until failure.

The Shapiro-Wilk test was used to test for normality. Each group was compared with the control group using an independent t-test, assuming unequal variances. All p values were 2-sided. A p value of <0.05 was considered statistically significant.

RESULTS

Respectively for the control, proximal, and distal group, the maximum torque was 81.8±5.1, 78.7±6.0, and 74.3±3.6 Nm, and the end torque was 80.7±5.9, 78.6±6.0, and 71.8±8.6 Nm (Table 2); only the difference between control and distal groups was significant ($p=0.005$ for maximum torque and $p=0.033$ for end torque).

All fractures in both control and proximal groups involved the distal 1/3 humerus (AO 13-C1 type). In the distal group, the fractures involved either the distal 1/3 humerus (n=6) or the screw-hole (n=2, Fig. 3); the difference between the 2 types of fracture was not significant in terms of maximum torque (75.7 vs. 70.0, $p=0.086$) or end torque (75.3 vs. 61.4, $p=0.40$).

Figure 3 A proximal humeral fracture involving the screw hole.

DISCUSSION

The peak axial torque for the humerus near the maximum shoulder external rotation at the end of the cocking phase in a throwing motion has been reported to be 92±16 Nm.[16] In cadavers aged 53 to 92 (mean, 75) years, the mean torsional strength of an intact humerus in external rotation was 53.1 Nm, but the range was 20.9 to 100 Nm, indicating high inter-specimen variability.[17] The peak torque for the fourth-generation composite humerus is reported to be 77.4±2.5 Nm,[12] which is consistent with that for humans,[16] cadavers,[17] and our controls (81.8±5.1 Nm). Thus, results of our study can be applicable to cadaveric bone.[12,16,17] A screw hole represents a 20% defect in cortical bone and causes a 34% reduction in torsional strength, whereas a 50% defect results in a 62% reduction.[18]

One limitation of our study was the use of a one-dimensional protocol to assess a very complex group of movements and forces acting on the humerus during a rotational moment. In addition, only a single size and type of interference screw was assessed. In clinical practice, different sizes and types of interference screw are available for use, including biocomposite, bioabsorbable polyetheretherketone interference screws. Screw placement immediately adjacent to the inferior insertion point of the pectoralis major tendon, closer to the transition point of metaphyseal to diaphyseal bone was not assessed.

CONCLUSION

Compared with proximal placement of an interference screw, distal placement decreased the maximum torque (though not significantly) and may increase the risk of proximal humeral fracture.

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DISCLOSURE

No conflicts of interest were declared by the authors.

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