Title

Retaining Or Excising The Supraspinatus tendon in Complex Proximal Humeral Fractures Treated With Reverse Prosthesis? A Biomechanical Analysis In Two Different Designs

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ABSTRACT

Purpose

We aimed to biomechanically evaluate the effect of the supraspinatus tendon on tuberosity stability using two different reverse shoulder arthroplasty (RSA) models for complex proximal humeral fractures (PHFs)

Methods

Four-part proximal humeral fractures were simulated in 20 cadaveric shoulders. Two different RSA designs were implemented: a glenosphere medialized model and a glenosphere lateralized model. Tuberosities were reconstructed, and displacement of bony fragments was measured (mm) by placing three sensors: in the humeral diaphysis (D), in the greater tuberosity (GT) and in the lesser tuberosity (LT). Axial forces were induced and measured in Newton (N). The test was performed twice in each specimen, with and without the supraspinatus tendon. The regression line (RL) was measured in mm/N.

Results

In the medialized model, the GT-D displacement was greater in the supraspinatus preserving model than that in the tendon excision model ($p<0.001$), as well as for the LT-D distance ($p<0.001$).

In the lateralized model, GT-D displacement and GT-LT distance was greater in the preserving model than that in the excision model ($p<0.001$, $p=0.04$).

Conclusion

The supraspinatus tendon excision had a positive biomechanical effect on tuberosity stability when performing RSA for PHFs.

Keywords: tuberosity reconstruction, reverse shoulder arthroplasty, supraspinatus, cadaveric study, rotator cuff excision, complex proximal humeral fractures.

Level of evidence: Basic Science Study. Cadaveric Study

INTRODUCTION

Reverse shoulder arthroplasty (RSA) has emerged as a viable treatment for complex proximal humeral fractures (PHFs) in the elderly, and many studies have supported its use [1-3]. However, no consensus exists regarding the need for tuberosity reattachment when treating complex PHFs with RSA.

The Grammont concept of reverse arthroplasty shifts the glenohumeral center of rotation (COR) inferiorly and medially from the native joint, improving the efficiency of the deltoid [4, 5]. Lateralization of the COR in RSA has been recently suggested as a potential benefit to limit the degree of scapular notching and improve the range of motion. This can be achieved by designing extended or thicker glenosphere components [6, 7] or using autograft bone spacers [8].

In the early reports on the use of RSA for acute fractures, tuberosities were not routinely reattached and were even resected [9]. Technical efforts have recently been performed to anatomically reattach the tuberosities[10], and this represents the current trend as described by several publications [2, 3, 11-13]. Tuberosity healing after RSA for PHFs has been shown to contribute to external rotation strength restoration [12, 13]. However, some controversy exists in the literature concerning the influence of tuberosity healing on outcomes [14].

The effect of the supraspinatus tendon on the greater tuberosity may represent a stress force that potentially affects tuberosity healing. Because RSA was designed to work without a rotator cuff, the surgeon has the option to preserve [3, 11] or excise [2, 12, 14] the supraspinatus tendon in complex PHF scenarios.

The objective of this study was to biomechanically test the effect of the supraspinatus tendon on tuberosity displacement using a medialized glenosphere design and a lateralized glenosphere design for the treatment of PHF with RSA. We hypothesized that the supraspinatus tendon may play a negative role in the stability of tuberosities when fixed to the humeral stem.

MATERIALS AND METHODS

Twenty fresh-frozen cadaveric shoulders were used for this study, with a mean age of 62 (54-72) years. Specimens had not had previous shoulder surgery.

Preparation of the specimens was performed according to a previous study description [15]. Two-thirds of the distal clavicle, the entire scapula and the entire arm were initially included. Soft tissue superficial to the rotator cuff was removed. All shoulders were dissected, and gross examination showed no evidence of rotator cuff tears, arthritis, fracture or prior surgery. The medial third of the scapula was rigidly fixed to a customized apparatus.

Fracture preparation

Two orthopedic surgeons reproduced a four-part proximal humeral fracture through the bicipital groove using an oscillating saw to separate the greater tuberosity (GT) from the lesser tuberosity (LT) by splitting the humeral head, as previously reported [16]. The rotator interval was also split to allow access to the articular surface. A surgical neck horizontal osteotomy of the proximal humerus was performed that preserved the subscapularis tendon fibers to reproduce the division of the humeral diaphysis (D) from the tuberosities. The split humeral head was excised, and the tuberosities were then trimmed to obtain the anatomic relationship when reduced around the humeral stem.

Reverse arthroplasty and the tuberosity construct

Two different RSA designs were employed. A Grammont medialized COR design RSA was implemented in 9 specimens (Delta Xtend™, DePuy, Warsaw, IN) with the following implants: a standard 27-mm baseplate, a 42-mm centered glenosphere, a 10-mm monoblock humeral stem in a neutral position, with 155º of humeral inclination and a standard polyethylene insert sized according to the tension.

The remaining 11 specimens were used for the lateralized COR model with a 3.5-mm thicker glenosphere (Humelock Reversed®, FX Solutions, Viriat, France). The specific implants included a 24-mm baseplate, a 36-mm centered glenosphere, a 10-mm humeral stem with 145º of humeral inclination and a polyethylene insert sized according to the tension.

The humerus was then transected distal to the deltoid tuberosity to fix the specimen to an aluminum bench vice. The tuberosities were reduced around the proximal humeral stem and sutured to the humeral shaft according to Boileau's suture technique [10] using #5 Ethibond Excel® (Ethicon, Somerville, NJ).

Sensor implantation and measurement technique

Three sensors were implanted in the final construct: one in the humeral D, one in the GT and one in the LT. The sensor placement was guided by digital calipers to reproduce the same setup distances for each specimen. Calibration was then performed to obtain a reproducible model to compare multiple analyses.

Consequently, three measurements were obtained for each experiment: the greater tuberosity to diaphysis (GT-D) distance, the lesser tuberosity to diaphysis (LT-D) distance and the greater tuberosity to lesser tuberosity (GT-LT) distance.

Progressive axial forces were induced through the supraspinatus, infraspinatus and subscapularis tendons using #5 Ethibond Excel® (Ethicon, Somerville, NJ) sutures and measured in Newtons (N). A customized traction device with a digital dynamometer (Dillon ED Junior Red Dynamometer®, Data Weighing Systems, Elk Grove, IL) was used to apply force.

Displacement of the sensors was analyzed using a digital tracker that included position sensors and a digital signal processor (Polhemus Liberty®, Polhemus, Colchester, VT). The test was performed twice on each specimen: first with retention of the supraspinatus tendon and, second, after supraspinatus tendon resection.

Statistical analysis

Linear mixed models were applied to determine the effect of the supraspinatus tendon on the relationship between the increase in distance and force. These models, fitted separately for each combination of implant type and sensor, included the interaction of the supraspinatus tendon type and force as a fixed effect and the individual as a random effect.

The slope of the regression line was measured in mm/N for each configuration to determine the effect size. Both regression lines (with and without the supraspinatus tendon) were forced to pass through the origin because the distance cannot be increased if no force is applied. The difference between the two regression slopes was considered the effect size measure. A positive value indicated a larger distance increase with the supraspinatus tendon given the same force as without the supraspinatus tendon. The level of significance was set at $p<0.05$. All statistical analyses were performed with R (R Foundation for Statistical Computing, Vienna, Austria.), version 3.3.1.

RESULTS

For both the medialized and lateralized COR models, all interfragmentary distances increased according to the forces applied, resulting in a positive regression line in all experiments (Fig. 1 and Fig. 2).

The medialized COR RSA model showed significant differences in the GT-D interfragmentary displacement when the supraspinatus tendon was preserved compared to that when it was resected (Fig. 1). The model showed a higher regression line (RL) when the supraspinatus tendon was preserved than that in the model where the supraspinatus tendon was resected ($p<0.001$) (Table 1). The LT-D interfragmentary distance (Fig. 1) exhibited a smaller regression line for the supraspinatus tendon excision model (RL: 0.047) than that for the tendon preserving model (RL: 0.065, $p<0.001$). Regarding the displacement between tuberosities (GT-LT distance), the construct showed small non-significant differences for the excision and preserving models ($p=0.07$) (Table 1).

In the lateralized COR RSA model, the GT-D interfragmentary displacement (Fig. 2) was greater in the supraspinatus preserving model than that in the supraspinatus excision model for the forces applied ($p<0.001$) (Table 1). The LT-D interfragmentary distance measurements (Fig. 2) showed no significant differences with and without the supraspinatus tendon ($p=0.97$) (Table 1). Regarding the GT-LT distance, a significant difference in the RL was found between the two models. The RL value was significantly higher for the excision model than that for the tendon retaining model ($p=0.004$) (Fig. 2).

DISCUSSION

RSA has currently gained popularity in the management of acute PHFs. The present study showed that the supraspinatus tendon is important for tuberosity stability in RSA performed for a PHF. This tendon excision plays a positive biomechanical role in the stability of tuberosity reconstruction via RSA, especially affecting the stability of the GT-D junction.

It is still unclear how tuberosity healing affects functional outcomes after RSA for PHF. In an early report, Cazeneuve et al. [9] excised the remnants of the tuberosities to prevent limitation of adduction and possible instability of the humeral component. Since then, different authors have reported their experience with the use of reverse prostheses for fractures. Sebastiá-Forcada et al. [3] reported no differences between tuberosity failure and healing subgroups according to the mean constant score of 31 patients. Chun et al. recently reported no differences in functional outcomes regardless of tuberosity healing in 38 patients [14]. In contrast, Gallinet et al. [12] observed better clinical outcomes of patients with tuberosity healing among a group of 41 patients.

Given the background, technical efforts have been made to enhance tuberosity healing, and consequently, increased emphasis on tuberosity repair for the restoration of rotational shoulder function has been recently noted [14, 17, 18]. Formaini et al. [11] proposed a hybrid cementation-impaction method with a cancellous bone graft to improve tuberosity healing, and an 88% tuberosity healing rate was reported. In some publications, the description of RSA for a PHF has included supraspinatus resection, but no clinical or biomechanical evidence suggests that this will increase the healing of the tuberosities [2, 12, 14].

The present study confirmed the involvement of the supraspinatus tendon in GT- and LT-mediated stability of the D in RSA. In the medialized model, resection of the supraspinatus tendon particularly has no effect on GT and LT stability. In the lateralized RSA model, the greater impact of the supraspinatus tendon seems to be focused on GT attachment stability to the D. However, when releasing the supraspinatus tendon, the forces through both tuberosities seemed to increase, contrary to the medialized design. This may be explained because the lateralized glenosphere may produce tension on the subscapularis tendon, infraspinatus tendon and teres minor when the supraspinatus tendon is absent. COR lateralization seems to significantly increase the joint loads, especially when the rotator cuff tendons are repaired [19]. In the lateralization scenario, the rotator cuff tendons may act as antagonists after RSA [20].

Based on the results obtained, some clinical applications may be advised. The surgeon has the option to either preserve or excise the supraspinatus tendon during the surgery. Preservation of the supraspinatus tendon may jeopardize tuberosity stability around the humeral stem in RSA. Reinforcement of the tuberosity sutures may favor bone fragment stability. Hence, the tuberosity stability may be favored when excising the tendon from the GT. When a COR lateralized RSA is performed with a supraspinatus excision, the surgeon must use a higher tension between both tuberosities. Then, the horizontal circumferential fixation suture may play a more important role in tuberosity stability. This effect was previously described by Frankle et al. [15] when studying the tuberosity reattachment stability in proximal humeral hemiarthroplasty.

The aim of this study was not to compare the two different RSA techniques. Differences between the designs are not limited to the COR. The authors do not consider the implants employed as comparable designs. Differences include the humeral inclination, humeral stem diaphysis and baseplate diameter. Therefore, a strict comparison of medialized and lateralized implants cannot be performed based on the findings of the present study. Nevertheless, the aim of this study was to analyze the effect of the supraspinatus tendon using two different RSA designs.

This study has several limitations. First, this is a biomechanical study. The clinical implications cannot be fully determined, as the authors idealized the fracture pattern by obtaining good quality bone fragments and reducing tuberosities with small fracture gaps. Second, cadaveric specimens were used with a mean age and gender distribution that may not represent the target population for RSA treatment due to a complex PHF. Third, the deltoid effect has not been analyzed. Lateralization and rotator cuff repair seem to interact with deltoid action regarding joint load magnitudes [21].

CONCLUSIONS

The supraspinatus tendon excision plays a positive biomechanical role in tuberosity stability when performing RSA for treatment of a PHF. Tendon resection leads to a more stable tuberosity construct for both medialized and lateralized RSA models.

CONFLICT OF INTEREST

The authors, their immediate family, and any research foundation with which they are affiliated did not receive any financial payments or other benefits from any commercial entity related to the subject of this article.

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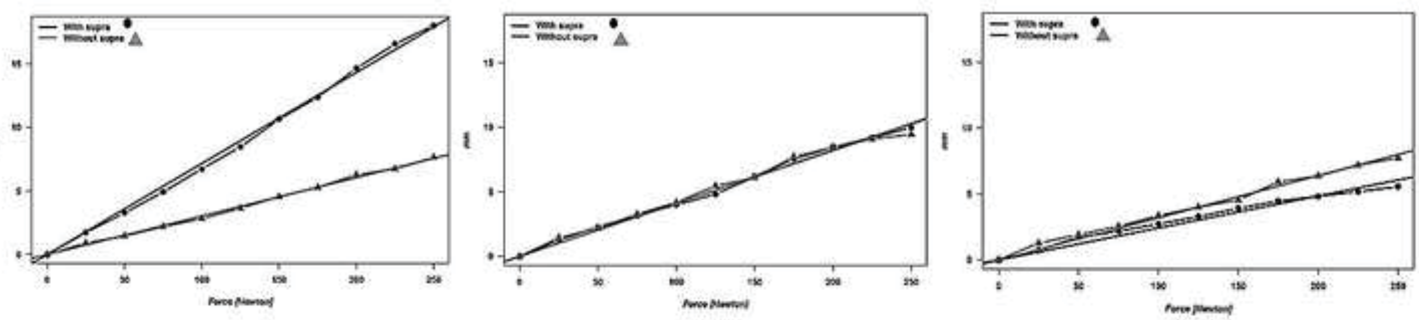
Figure 1

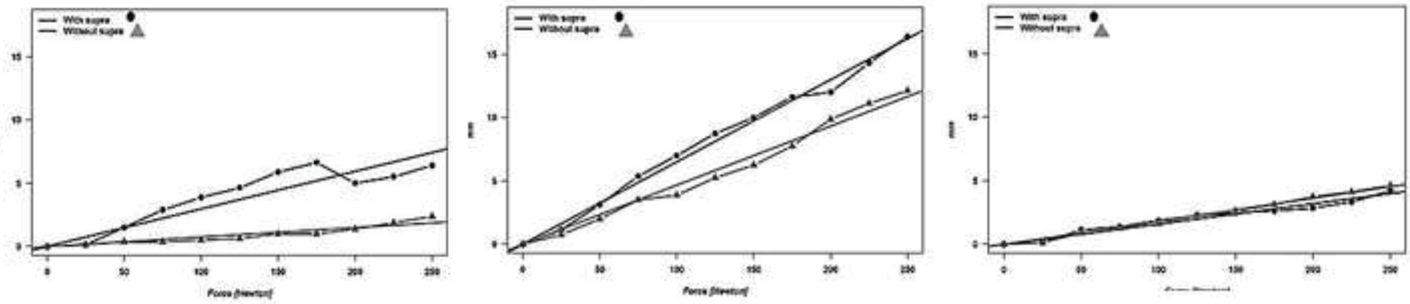


GT-D interfragmentary displacement

LT-D interfragmentary displacement

GT-LT interfragmentary displacement

Figure 2 Click here to download Figure FIGURE 2.power media player.windows.jpg



GT-D interfragmentary displacement

LT-D interfragmentary displacement

GT-LT interfragmentary displacement

Table 1. Estimated slopes of regression lines for three different distances in both medialized and lateralized COR models.

	RL for supraspinatus preservation models (mm/N)	RL for supraspinatus excision models (mm/N)	P value
Medialized model			
GT-D distance	0,032	0,007	<0,001
LT-D distance	0,065	0,047	<0,001
GT-LT distance	0,015	0,018	0,07
Lateralized model			
GT-D distance	0,072	0,031	<0,001
LT-D distance	0,040	0,040	0,975
GT-LT distance	0,023	0,030	0,004

COR, Center of rotation; RL, Regression line; GT-D, Greater tuberosity to diaphysis distance; LT-D, Lesser tuberosity to diaphysis distance: GT-LT, Greater tuberosity to lesser tuberosity distance. The p values correspond to the null hypothesis that the slopes of the regression lines are the same.