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Effect of Preoperative Fatty Degeneration of the Deltoid and the Teres Minor Muscles on the Clinical Outcome after Reverse Total Shoulder Arthroplasty

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Background: To evaluate the effect of preoperative fatty degeneration of deltoid and teres minor muscles on the clinical outcome in patient with reverse total shoulder arthroplasty (RTSA).
Methods: Nineteen patients with RTSA were enrolled. The mean follow-up period was 16.1 months. The fatty degeneration of three distinct parts in each deltoid and the teres minor muscle was measured using a preoperative magnetic resonance imaging. Postoperatively, the muscle strengths for forward elevation (FE), abduction (Abd), and external rotation (ER) were measured using a myometer at the last follow-up. The parameters for clinical outcome were Constant Score (CS) and Korean Shoulder Score (KSS).
Results: The number of cases was 10 in group 1 and 9 in group 2. The strength of FE and Abd were significantly higher in group 1 ($p<0.001$ and $p<0.001$, respectively), and the strength of ER was not different significantly between two groups ($p=0.065$). For the clinical outcome, both CS and KSS were higher in group 1 ($p=0.002$ and $p=0.002$, respectively). The number of patients in group A was 11, and group B was 8. Although there was not a significant difference in terms of FE and Abd between group A and B ($p=0.091$, $p=0.238$), ER was significantly higher in group A ($p=0.012$). We did not find a significant difference in the clinical scores (CS, $p=0.177$ and KSS, $p=0.238$).
Conclusions: These findings suggest the importance of a preoperative evaluation of the fatty degeneration of deltoid and teres minor muscles for predicting postoperative strength and clinical outcome.
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Key Words: Massive rotator cuff tear; Cuff tear arthropathy; Reverse total shoulder arthroplasty; Deltoid fatty degeneration; Teres minor fatty degeneration

Introduction

Despite the many treatment methods that had been proposed for the repair of the massive rotator cuff tears and of the cuff tear arthropathy, none had shown a satisfactory clinical outcome.[1-6] However, with the advent of Grammont's approach[7,8] of Delta III reverse prosthesis, satisfactory clinical outcomes were beginning to show. The use of reverse total shoulder arthroplasty (RTSA), a protocol based on the principles of Delta III reverse prosthesis, has been increasing for its efficacy in the treatment of massive cuff tear and cuff tear arthropathy.[9-11] The biomechanical characteristic of RTSA is to increase the tension of the deltoid muscle by inducing a medial shift of the axis of rotation and an inferior migration of the humerus.[12] Therefore, the tension of the deltoid muscle is increased so that the ability of the muscle to execute forward elevation (FE) and the abduction (Abd) functions can be improved. It is thought that the condition of the deltoid muscle is closely correlated with postoperative outcome. The number of studies reporting the effect of the preoperative fatty degeneration of the deltoid muscle on clinical outcome is few.[13] Several reports show a decreased postoperative external rotation (ER) and functional decline after RTSA.[12,14,15] Simovitch

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et al.[16] reported that a preoperative fatty degeneration of remnant rotator cuffs affect on postoperative clinical outcome, but the amount of other corroborative study are not enough. In this study, we investigate the effect of preoperative deltoid fatty degeneration and teres minor fatty degeneration on the functional and clinical outcomes of RTSA. Our hypothesis is that a relationship between deltoid fatty degeneration and postoperative FE and Abd exists and a relationship between teres minor fatty degeneration and postoperative ER exists.

Methods

Subjects of Study

From March 2012 and June 2013, we enrolled 19 patients who underwent an RTSA and could be followed-up at least one year into our retrospective study. Those with the following indications were eligible for RTSA: an irreparable massive rotator cuff tear or a cuff tear arthropathy. A patient with a massive rotator cuff tear was defined as someone having at least 2 complete tears of the rotator cuff tendon or a complete tear of the supraspinatus tendon combined with a partial tear of at least 50% of the subscapularis tendon or the infraspinatus tendon. In total, there were 8 cases of massive tears of the rotator cuff; 5, complete tears of the supraspinatus, subscapularis, or the infraspinatus tendons; 1, complete tears of the supraspinatus and infraspinatus tendons; 1, complete tears of the supraspinatus and subscapularis tendons; and 1, partial tears of subscapularis and infraspinatus tendons with a concomitant complete tear of the supraspinatus tendon. There were 11 cases of cuff tear arthropathy, 4 cases of complete tears of the supraspinatus, subscapularis, and infraspinatus tendons, 3 cases of complete tears of the supraspinatus and infraspinatus tendons, 3 cases of tears of the supraspinatus and subscapularis tendons, and 1 cases of complete tear of the supraspinatus tendon combined with partial tears of the subscapularis and infraspinatus tendons. The mean age of the enrolled patients was 71.9 years (range, 60 to 80 years). The mean follow-up period was 16.1 months (range, 12 to 26 months). The gender ratio was 4 males to 15 females.

Measuring the Extent of Preoperative Fatty Degeneration in the Deltoid and Teres Minor Muscles

1) Fatty degeneration of the deltoid muscle

We measured the preoperative level of fatty degeneration in each of the 3 portions of the deltoid muscle (the anterior, lateral, and posterior) at the infra-glenoid level using the following magnetic resonance imaging (MRI) scans: T1-weighted oblique coronal image, T1-weighted oblique sagittal image, and axial image.

According to Kapandji[17] the deltoid muscle can be functionally compartmentalized into 7 parts starting from the lower plane: the anterior portion, segments 1 and 2, comprises the deltoid root arising from the clavicle, also called the clavicular band; the lateral portion, segment 3, comprises the deltoid root from the acromion, also called the acromial band; lastly, the posterior portion, segments 4 to 7, comprises the spinal band where the deltoid roots from the scapular spine. In our study, we measured the fatty degeneration of each deltoid region (anterior, lateral, and posterior) using the method described by Fuchs et al.[18] and categorized them into stages set out by Goutallier et al. (Fig. 1).[19]

For there are no reference of criteria for deltoid fatty degeneration which affect clinical outcome, we need to set up new criteria for grouping. So, we concerned that the number of each group would be similar and differences of fatty degeneration between groups would be significant for making criteria. As well as measuring the amount of fatty degeneration in each portion of the deltoid, we calculated the average of the three. In this study, we decided to use a threshold Groutallier stage of 1.5. If a patient had a deltoid fatty degeneration of less than 1.5, they were allocated into group 1, or if they had a deltoid fatty degeneration of more than 1.5, into group 2.

2) Fatty degeneration of the teres minor muscle

We measured the preoperative level of fatty degeneration using two MRI scans: the T1-weighted oblique sagittal image looking specifically at the scapular 'Y' which is the point where the scapular spine meets the scapular body and the axial image. We then classified the fatty degeneration into stages of severity in the same way we did for the fatty degeneration of the deltoid muscle (Fig. 2). Patients with stages 0 to 2 of fatty degeneration of the teres minor muscle were grouped into group A, and those with stages 3 and 4, into group B.

Implants and Methods

As the prosthetics, we used the Bony Increased Offset (BIO)-RSA (Tornier, Montbonnot Saint Martin, France) and the lateralized glenoid sphere following the Aequalis™ Reversed shoulder system (Tornier). The surgery was carried out with the patient in a beach-chair position and using the deltoid-pectoral approach.

Measurement of Postoperative Muscle Strength

At the final follow-up we measured the muscle strengths during FE, Abd, and ER using the Commander dynamometer (Jtech Medi, Midvale, UT, USA). The muscle strengths were measured in the following ways: the patient was placed with the arm at 90° of FE and the FE was measured as how far they could best resist an opposing force; in the same position but with the arm at 80° of Abd, the Abd force was measured in a similar way; and lastly, the patient was asked to place the elbow in 90° of flexion, while the arm at side, and ER was measured as how far the patient could resist an internal rotational force from the 0° position (Fig. 3).

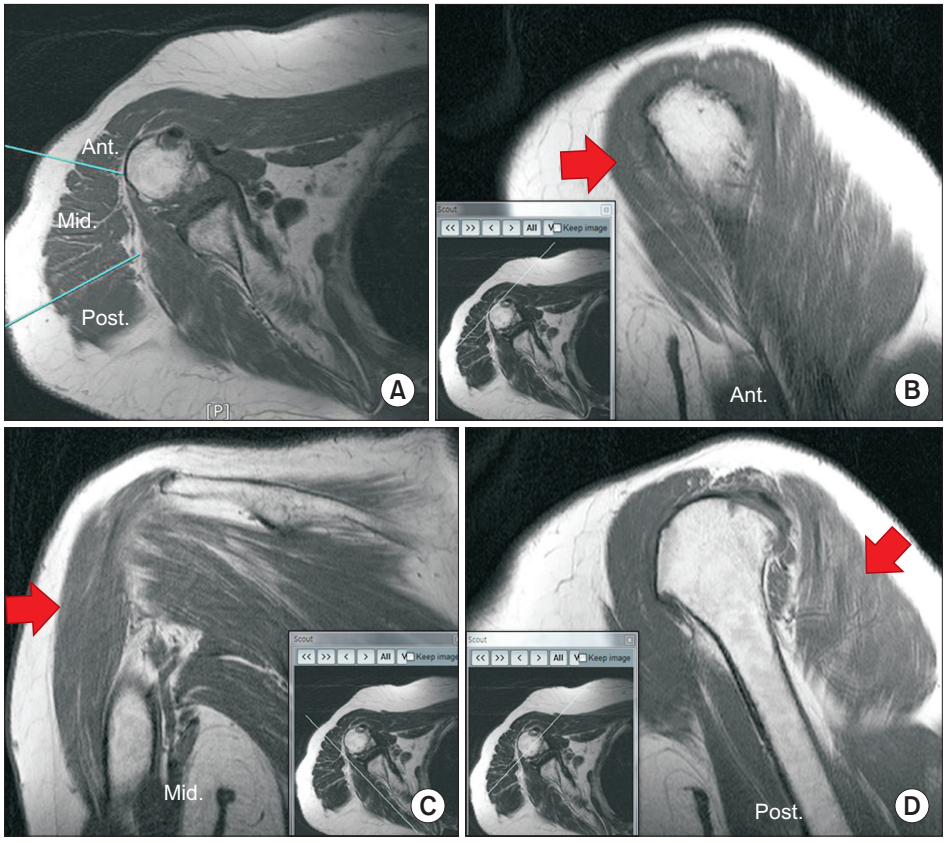

Fig. 1. Measuring the amount of fatty degeneration of the deltoid muscle. (A) The deltoid was divided into three portions (anterior [Ant.], middle [Mid.], and posterior [Post.]) at the level of the infra-glenoid rim. (B) The anterior deltoid fatty degeneration was measured using a T1-weighted axial image and an oblique sagittal image (arrow: insert). (C) The lateral deltoid fatty degeneration was measured using a T1-weighted axial image and an oblique coronal image (arrow: insert). (D) The posterior deltoid fatty degeneration was measured using a T1-weighted axial image and an oblique sagittal image (arrow: insert).

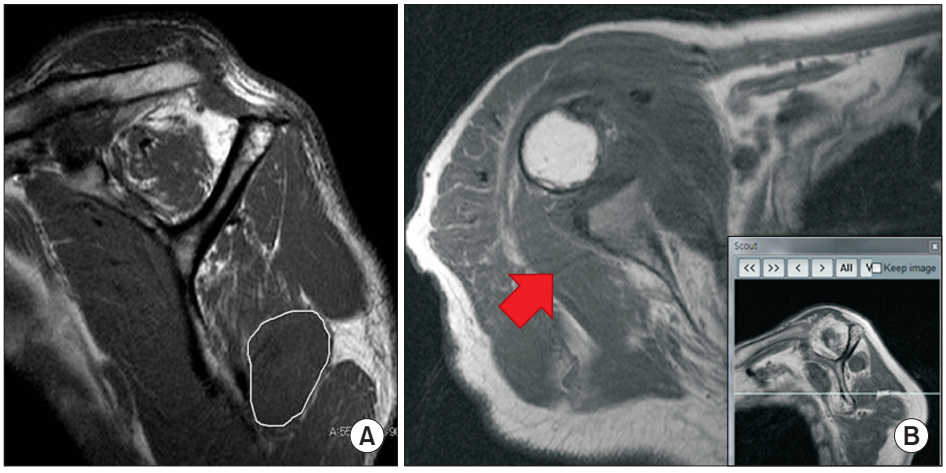

Fig. 2. Measuring the amount of fatty degeneration of the teres minor muscle. (A) Teres minor was located on the scapular 'Y' view of an T1 oblique sagittal image. (B) A T1-weighted axial image was also taken (arrow: insert).

Clinical Assessment

The Constant score (CS) and Korean shoulder score (KSS)–our markers of clinical outcome–were measured at the final postoperative follow-up.

Statistical Analysis

The statistical analysis of the comparison between groups according to deltoid and teres minor fatty degeneration for postoperative muscle strengths and clinical outcomes was made using the Mann-Whitney U test and the IBM SPSS statistical package ver. 19.0 (IBM Co., Armonk, NY, USA).

Results

The number of patients in group 1 those with lower fatty degeneration of the deltoid muscle was 10, and the number of patients in group 2 those with higher fatty degeneration was 9. We found that the postoperative muscle strength of FE was 22.40 ± 5.68 lb in group 1 and 14.72 ± 2.00 lb in group 2 ($p<0.001$), the strength of Abd was 20.63 ± 5.89 lb in group 1 and 13.22

Fig. 3. Measurement of the postoperative muscle strength. (A) Forward elevation. (B) Abduction. (C) External rotation.

Table 1. Comparison of the Clinical Outcomes between Group 1 and Group 2 according to Deltoid FD

Variable	Group 1 (n=10)	Group 2 (n=9)	*p*-value
Strength (lb)			
FE	22.40 ± 5.68	14.72 ± 2.00	<0.001
Abd	20.63 ± 5.89	13.22 ± 2.06	<0.001
ER	12.95 ± 3.75	9.72 ± 2.40	0.065
Clinical score			
CS	75.70 ± 7.39	60.00 ± 9.75	0.002
KSS	79.80 ± 4.92	65.89 ± 9.91	0.002

Values are presented as mean ± standard deviation.
Group 1: fatty degeration (FD) <1.5, Group 2: FD ≥1.5, FE: forward elevation, Abd: abduction, ER: external rotation, CS: Constant score, KSS: Korean shoulder score.

Table 2. Comparison of Clinical Outcomes between Two Groups according to Teres Minor FD

Variable	Group A (n=11)	Group B (n=8)	*p*-value
Strength (lb)			
FE	20.86 ± 6.48	15.88 ± 3.07	0.091
Abd	18.80 ± 6.90	14.81 ± 2.83	0.238
ER	12.95 ± 3.53	9.31 ± 2.27	0.012
Clinical score			
CS	72.00 ± 11.33	63.13 ± 10.49	0.177
KSS	75.82 ± 9.35	69.63 ± 11.14	0.238

Values are presented as mean ± standard deviation.
Group A: fatty degeration (FD) ≤2, Group B: FD >2, FE: forward elevation, Abd: abduction, ER: external rotation, CS: Constant score, KSS: Korean shoulder score.

± 2.06 lb in group 2 (p<0.001); both values were significantly higher in group 1 than in group 2. But the postoperative muscle strength of ER, 12.95 ± 3.75 lb in group 1 and 9.72 ± 2.40 lb in group 2, did not show a statistically significant difference (p=0.065). In terms of the relationship between deltoid fatty degeneration and clinical outcome, we found that compared to group 2, group 1 showed a significantly improved clinical outcome; CS was 75.70 ± 7.39 lb in group 1 and 60.00 ± 9.75 lb in group 2 (p=0.002), and KSS was 79.80 ± 4.92 lb in group 1 and 65.89 ± 9.91 lb in group 2 (p=0.002) (Table 1).

The number of patients in group A those with lower fatty degeneration of the teres minor muscle was 11, and the number of patients in group B those with higher fatty degeneration was 8. Although there was not a significant difference in terms of FE and Abd between group A and B (FE, 20.86 ± 6.48 lb vs. 15.88 ± 3.07 lb; Abd, 18.80 ± 6.90 lb vs. 14.81 ± 2.83 lb) (p=0.091, p=0.238), we found that ER was significantly higher in group A than in group B (12.95 ± 3.53 lb vs. 9.31 ± 2.27 lb) (p=0.012). We did not find a significant difference in the clinical scores between the two groups. The CS was 72.00 ± 11.33 lb in group A and 63.13 ± 10.49 lb in group B, and the KSS was 75.82 ± 9.35 lb in group A and 69.63 ± 11.14 lb in group B (p=0.177, p=0.238) (Table 2).

Discussion

In this study we investigated the effect of preoperative levels of deltoid fatty generation and teres minor fatty degeneration on the functional and clinical outcomes of RTSA. We found that patients who have a low degree of preoperative deltoid fatty degeneration are significantly associated with a greater improvement in postoperative FE and Abd strengths and better clinical outcomes than those who have a high degree of fatty degeneration. Further, we found that patients who have a low degree of preoperative teres minor fatty degeneration are significantly associated with a higher postoperative ER strength. On the basis of this study, we can conclude that the extent of fatty degeneration in deltoid muscle can influence the postoperative FE and Abd, and the extent of fatty degeneration in teres minor muscle can influence the postoperative ER.

It was reported by Grammont that the mechanical hallmarks of RTSA are the medial shift of the axis of rotation of the shoulders and the inferior migration of the humerus. The shifting of the rotational axis medially increases the contribution of the

muscle fiber of the deltoid muscle to execute mechanical functions such as FE and Abd. The inferior migration of the humerus increases the tension of the deltoid muscle, thereby, strengthening its functional role.[12] Several studies support these biomechanical effects of RTSA.[20-24] For instance, Jobin et al.[25] found that extension the deltoid muscle is significantly associated with postoperative active FE. They reported the predictive value of the acromion-greater tuberosity distance in estimating the postoperative active FE. Another study by Schwartz et al.[26] using cadavers found that after RTSA the Abd moment at the anterior and the middle fibers of the deltoid muscle increased. Especially, they reported that with loss of the anterior deltoid muscle there was a significant loss in Abd and forward flexion of the arm. These studies suggest the implication of the anterior deltoid muscle for the successful outcome of RTSA.

It is not uncommon to see that ER is not improved or even deteriorates after RTSA. Boileau et al.[12] suggested possible factors that could contribute to this: a limited lateral offset of the glenosphere, which is characteristic of prostheses, restricts the range of lateral rotation of the humerus; loss in posterior deltoid mass and the loosening of remaining muscles involved in ER, such as the infraspinatus and the teres minor muscles, leads to less of a compensatory role than they should play to make up for the weakened external rotational force with the medial movement of the humeral rotational axis; and the preoperative condition of the remaining teres minor muscle. Ackland et al.[20] also reported a functional loss in ER of the posterior deltoid muscle after RTSA. Not only did they find that the largest postoperative ER moment occurs in the teres minor muscle and the lower infraspinatus tendon, they found that posterior deltoid muscle influences ER when the arm is in FE and in Abd. It is difficult to derive a statistically significant inference regarding the role of the preoperative infraspinatus muscle on the outcome of RTSA as there were only 4 out of 19 cases where there was no infraspinatus tear.

Thus far, our evidence and those of others show the importance of the deltoid muscle and the teres minor muscle on the clinical outcomes after RTSA. Still, more corroborating reports that support the effect of preoperatively altered deltoid and teres minor muscles on outcomes after RTSA are needed.

In their study on 23 patients, Greiner et al.[13] investigated the effect of fatty degeneration in the deltoid muscle and in the rotator cuff on CS, Abd, and active ER after RTSA. They found that extent of fatty degeneration of deltoid muscle was correlated to clinical outcome and that patients with a longer follow-up were associated with a greater fatty degeneration of the deltoid. Intriguingly, they found that although fatty degeneration of the different parts of the rotator cuffs did not show a difference in their association with the clinical outcome, the fatty degeneration in the anterior part and the lateral part of the deltoid muscle differed in terms of their association with the clinical outcome.

In this study, we performed a comparative analysis of the clinical outcomes and muscle function between varying extents of preoperative deltoid and teres minor fatty degeneration. We found that the clinical parameters, CS and KSS, and parameters of muscle function FE and Abd of the arm were significantly higher in patients with a lower fatty degeneration of the deltoid muscle than patients with a higher degree of degeneration. In this study, we found that patients with lower levels of teres minor fatty degeneration showed a significantly higher ER after RTSA than those with higher levels of fatty degeneration. But the clinical scores, CS and KSS, despite both groups showing a high score, did not show a statistically significant difference between the two groups. In agreement to our findings Boileau et al.[12] reported that fatty degeneration in the teres minor muscle affects postoperative functional outcome, such as active ER and found that patients with low teres minor fatty degeneration were significantly associated with an improved CS. Further, Simovitch et al.[16] reported that a low preoperative fatty degeneration of the teres minor muscle is significantly correlated to a high postoperative CS and Subjective Shoulder Value and enhanced postoperative ER.

A few limitations to this retrospective study exist. First, the relatively small sample of patients limits the statistical power of this study. Second, the study design involved a relatively short follow-up. A further, prospective study involving a larger patient sample size and a longer follow-up is required. Third, during the operation of the study, we found that accurately measuring the fatty degeneration of the deltoid muscle section by section was difficult using MRI not only because the borders of the deltoid sections are inconspicuous but there is currently no standardized protocol on the differentiation of each deltoid portion to follow. Although in this study we used Greiner et al.'s approach[13] to measure fatty degeneration at the level of the infra-glenoid rim, future radiologic and anatomical studies are needed to support our assessment of fatty degeneration.

Conclusion

In patients treated using RTSA, we found that preoperative fatty degeneration of the deltoid muscle was significantly correlated to the postoperative muscle strengths during FE and Abd of the arm and to the clinical outcome. We also found that the preoperative fatty degeneration of the teres minor muscle was significantly correlated to postoperative muscle strength during ER. These findings suggest the importance of a preoperative evaluation of the fatty degeneration of deltoid and teres minor muscles for predicting postoperative strength and clinical outcome.

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