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The clinical and structural long-term results of open repair of massive tears of the rotator cuff

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The Clinical and Structural Long-Term Results of Open Repair of Massive Tears of the Rotator Cuff

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Background: At a mean follow-up of 3.1 years, twenty-seven consecutive repairs of massive rotator cuff tears yielded good and excellent clinical results despite a retear rate of 37%. Patients with a retear had improvement over the preoperative state, but those with a structurally intact repair had a substantially better result. The purpose of this study was to reassess the same patients to determine the long-term functional and structural results.

Methods: At a mean follow-up interval of 9.9 years, twenty-three of the twenty-seven patients returned for a review and were examined clinically, radiographically, and with magnetic resonance imaging with use of a methodology identical to that used at 3.1 years.

Results: Twenty-two of the twenty-three patients remained very satisfied or satisfied with the result. The mean subjective shoulder value was 82% (compared with 80% at 3.1 years). The mean relative Constant score was 85% (compared with 83% at 3.1 years). The retear rate was 57% at 9.9 years (compared with 37% at 3.1 years; $p = 0.168$). Patients with an intact repair had a better result than those with a failed reconstruction with respect to the mean absolute Constant score (81 compared with 64 points, respectively; $p = 0.015$), mean relative Constant score (95% and 77%; $p = 0.002$), and mean strength of abduction (5.5 and 2.6 kg; $p = 0.007$). The mean retear size had increased from 882 to 1164 mm^2 ($p = 0.016$). Supraspinatus and infraspinatus muscle fatty infiltration had increased ($p = 0.004$ and 0.008, respectively). Muscles with torn tendons preoperatively showed more fatty infiltration than muscles with intact tendons preoperatively, regardless of repair integrity. Shoulders with a retear had a significantly higher mean acromion index than those without retear (0.75 and 0.65, respectively; $p = 0.004$).

Conclusions: Open repair of massive rotator cuff tears yielded clinically durable, excellent results with high patient satisfaction at a mean of almost ten years postoperatively. Conversely, fatty muscle infiltration of the supraspinatus and infraspinatus progressed, and the retear size increased over time. The preoperative integrity of the tendon appeared to be protective against muscle deterioration. A wide lateral extension of the acromion was identified as a previously unknown risk factor for retearing.

Level of Evidence: Therapeutic Level IV. See Instructions to Authors for a complete description of levels of evidence.

The prevalence of rotator cuff tears depends on age, but it may be >50% in asymptomatic patients who are more than sixty years old[1]. In relatively young, working persons, however, large tears are incompatible with heavy manual labor[2,3] and constitute a substantial medical and socioeconomic problem[4]. They are frequently associated with pain, weakness[5], and functional disability[6]. Massive rotator cuff tears, defined as tears with detachment of at least two complete tendons[6], have an unfavorable treatment history, and repair is technically difficult and associated with a distinctly higher retear rate than that associated with the repair of smaller tears[7-11].

We prospectively studied twenty-seven consecutive patients treated with a laboratory tested, clinically established repair technique[12,13]. The preoperative findings and the results at an average of 3.1 years postoperatively were documented clinically and radiographically and with magnetic resonance imaging studies[6]. At the time of the early follow-up evaluation, the patients had improved significantly ($p < 0.05$) with regard to pain score, function, and strength despite progression of

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fatty infiltration of the affected muscles. The documented structural retear rate was 37%, and the functional outcome was significantly ($p < 0.05$) inferior in the shoulders with a failure of the repair. The long-term clinical and structural outcome of intact or structurally failed repairs of massive rotator cuff tears is currently unknown, and we know of no information on how well early results predict long-term outcome.

Therefore, the purposes of this study were to determine the clinical and structural long-term results after open repair of massive rotator cuff tears in patients who had been examined with the same, standardized methodology at a mid-term follow-up evaluation[6] and to identify additional risk factors for the long-term outcome.

Materials and Methods

Patient Data

Twenty-three of the twenty-seven patients described in a previous study[6] returned for an examination with use of the identical clinical, radiographic, and magnetic resonance imaging methodology used at the follow-up evaluation at a mean of 3.1 years[6,14-17]. Four patients were lost to follow-up between the 3.1-year evaluation and the present 9.9-year evaluation. Two of them had died of unrelated causes, and two were unable to attend the follow-up examination because of medical problems unrelated to the involved shoulder. The two patients who could not be reexamined were interviewed by telephone. Their subjective clinical results had remained unchanged. At 3.1 years, the subjective shoulder value was 100% for both and they had a relative Constant score[18,19] of 100% and 94%. However, these two patients were excluded from all analyses throughout the study. The average age of the twenty-three patients in the study was fifty-four years (range, forty-two to sixty-seven years) at the time of rotator cuff repair.

In the fifteen men and eight women, the dominant arm was involved in eighteen patients. Ten patients had initially had an anterosuperior tear (supraspinatus and subscapularis), six patients had a posterosuperior tear (supraspinatus and infraspinatus), and seven patients had a three-tendon tear.

Surgical Technique and Postoperative Care

Open rotator cuff repair with use of a transosseous tendon reinsertion and augmentation technique had been performed in all twenty-three patients as described in detail in the previous report[6]. All operations were performed by the senior author (C.G.) using the superolateral approach. Musculotendinous units were mobilized to allow repair to their original insertion site with use of a transosseous technique with number-3 braided sutures and modified Mason-Allen stitches[12,13]. In all shoulders, a small titanium plate (Synthes, Waldenburg, Switzerland) was used as a cortical augmentation device to increase transosseous cut out strength. Postoperatively, patients wore a sling when the supraspinatus and infraspinatus had been repaired without tension, and an abduction splint was worn for six weeks if the supraspinatus and infraspinatus were repaired under mild tension. Postoperatively, strictly passive exercises were performed under the supervision of a physical therapist. Active exercises were not started before six weeks postoperatively, and strengthening exercises were begun after twelve weeks.

Clinical Assessment

For the purpose of this study, all patients were examined by two investigators (M.A.Z. and J. Hempel) different from the operating surgeon (C.G.) at an average of 9.9 years (range, 6.7 to 12.8 years) after the index operation. The follow-up clinical assessment was performed with a structured interview and a detailed physical examination as previously described[6]. The subjective satisfaction of the patients was assessed by two different parameters. First, patients were asked to qualify the result in the involved shoulder by selecting one of the four possibilities: very satisfied, satisfied, disappointed, or not satisfied[6,20-22]. Additionally, the patients had to estimate the value of the involved shoulder as a percentage of that of an entirely normal shoulder, with the latter being 100%. This value was called the subjective shoulder value[6,20-23]. Clinical examination was performed according to the Constant and Murley score[18,19], which is based on a scale of 100 points, with 35 points allocated for subjective variables (pain, activity of daily living, and functional use of the arm); 40 points, for objective measurements (range of motion); and a maximum of 25 points, for the quantitative measurement of abduction. Abduction strength was measured with an Isobex dynamometer (Cursor, Bern, Switzerland) with the shoulder in 90° of abduction. If 90° of abduction could not be reached, abduction strength was automatically considered to be zero. The total score obtained in points was also related to the age and sex-matched normal values, which had been identified by Constant, and the respective value, given as a percentage, was termed the relative Constant score[24].

Radiographic Assessment

Preoperatively, at 3.1 years, and at the time of the latest follow-up, all patients underwent a standardized radiographic examination (a true anteroposterior radiograph with the arm in neutral rotation as well as transscapular and axillary radiographs) under fluoroscopic control. The acromiohumeral distance was measured in millimeters on the anteroposterior radiograph. Glenohumeral osteoarthritic changes were assessed on the anteroposterior and axillary lateral radiographs according to the classification of Samilson and Prieto[25].

The acromion index was measured as described by Nyffeler et al.[26]. The lateral extension of the acromion was assessed on a true anteroposterior shoulder radiograph with use of three parallel lines. The first line connected the superior and inferior osseous margins of the glenoid cavity and represented the plane of the glenoid articular surface. The second parallel line ran through the lateral border of the acromion, and the third parallel line was tangent to the most lateral part of the proximal part of the humerus. The distances from the glenoid to the acromion (GA) and from the glenoid to the lateral aspect of the humeral head (GT) were measured. The relationship between these two distances (GA/GT) was calculated and termed the acromion index (AI) (Fig. 1).

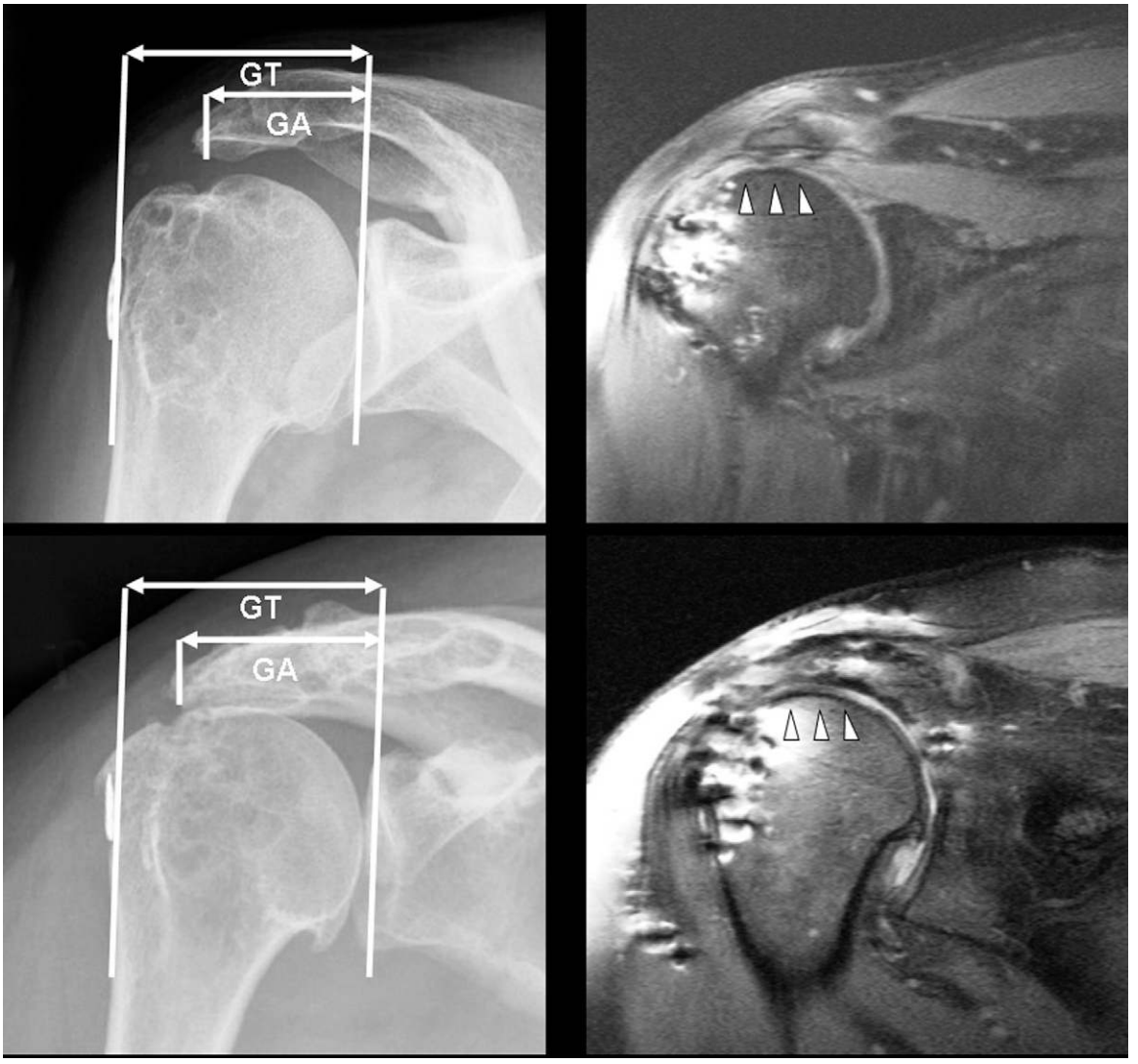

Fig. 1

Standardized, true anteroposterior radiographs (left) with corresponding T2-weighted coronal magnetic resonance images (right), made at the 9.9-year follow-up examination, of two patients. For one patient (top), the radiograph shows a low acromion index[26] (AI = GA/GT) of 0.55 and the corresponding magnetic resonance image shows the supraspinatus tendon to be in continuity (arrowheads). For the other patient (bottom), the radiograph shows a high acromion index of 0.80 and the corresponding magnetic resonance image shows a retear of the supraspinatus tendon (arrowheads). GA = the distance from the glenoid to the acromion, and GT = the distance from the glenoid to the lateral aspect of the humeral head.

Magnetic Resonance Imaging

All twenty-three patients also had a standardized magnetic resonance imaging examination with a 1.0-T scanner (Impact/Expert; Siemens Medical Solutions, Erlangen, Germany) or a 1.5-T scanner (Symphony or Avanto; Siemens Medical Solutions), with use of the same protocol as previously reported[6] (with minor changes adapting to technological advances). The same independent and experienced musculoskeletal radiologist (J. Hodler) analyzed the magnetic resonance imaging scans just as in the previous study[6] and was blinded to the surgical procedure, the clinical results, and the previous results. Parasagittal T1-weighted turbo spin-echo magnetic resonance imaging scans (repetition time, 450 to 700 msec; echo time, 12 msec), made parallel to the glenohumeral joint, were acquired for qualitative and quantitative assessment of the rotator cuff muscles[17]. The slices covered the rotator cuff from the humeral tuberosities to the medial third of the scapula. The thickness of the slices was 4 to 5 mm, with an interslice gap of 1.2 to 1.5 mm. Intramuscular fatty degeneration was assessed with use of the criteria established by Goutallier et al.[15] for computed tomography and adapted by Fuchs et al.[14] for magnetic resonance imaging.

The degree of fatty infiltration was measured according to Zanetti et al.[17] on parasagittal views on the most lateral image where the scapular spine was still in contact with the remainder

TABLE I Comparison of Clinical Parameters at the Preoperative, Mid-Term, and Long-Term Follow-up Evaluations

	Entire Series (N = 23)						
	Preop.*	Comparison of 3.1-Yr and Preop.† *(p value)*	3.1-Yr Postop.*	Comparison of 3.1-Yr and 9.9-Yr† *(p value)*	9.9-Yr Postop.*	Comparison of 9.9-Yr and Preop.† *(p value)*	Friedman Test‡ *(p value)*
Subjective shoulder value§ *(%)*			80	0.82	82		NS
Constant score#							
Absolute *(points)*	41	0.0001	70	0.08	71	0.0002	0.0001
Relative *(%)*	51	0.0001	83	0.56	85	0.0002	0.0001
Pain *(points)*	6.2	0.003	13.2	0.15	12.6	0.0004	0.0001
Activities of daily living *(points)*	5.2	0.0001	8.4	0.59	8.7	0.0001	0.0001
Functional use of arm *(points)*	6.1	0.0001	9.1	1.0	9.2	0.0001	0.0001
Active mobility							
Flexion *(deg)*	101	0.0001	145	0.96	144	0.0010	0.0001
Abduction *(deg)*	86	0.0001	136	0.38	131	0.0010	0.0001
External rotation *(deg)*	38	0.36	39	0.52	41	0.16	0.39
Internal rotation**	5.5	0.11	6.8	0.004	8.3	0.004	0.0001
Strength of abduction†† *(kg)*	1.9	0.43	2.9	0.05	3.8	0.14	NS

*The values are given as the average. †Wilcoxon signed-rank test (the level of significance was a p value of <0.017 with use of the Bonferroni-Dunn post hoc test). ‡The p value for differences between all three groups. NS = not significant. §Patient estimation of the value of the involved shoulder as a percentage of that of an entirely normal shoulder. #The absolute score is the average of the points given according to the system of Constant and Murley[18]. The relative Constant score is a percentage of an age and sex-related normal value[19]. **According to the system of Constant and Murley[18,19]. ††Strength in kilograms measured with an Isobex dynamometer.

of the scapula. Retears of the rotator cuff tendons were assessed with use of established magnetic resonance imaging criteria[16,27,28]. When a fluid-equivalent signal or nonvisualization of the supraspinatus, infraspinatus, or subscapularis tendon was found in one or more standard T2-weighted images or fat-suppressed proton-density or T2-weighted images, the diagnosis of a full-thickness retear was made. Retear sizes at the time of the final follow-up were compared with the retear sizes found at 3.1 years by using the maximal mediolateral and anteroposterior diameters.

Statistical Analysis

Nonparametric statistical analysis was performed with use of SPSS for Windows (version 11.0; SPSS, Chicago, Illinois). The Friedman test was performed for comparison among three groups. The Mann-Whitney test was used for unpaired groups, and the Wilcoxon test was used for paired groups, including a Bonferroni-Dunn correction. The level of significance was set at a p value of <0.05 for comparisons between two groups and the Friedman test, and it was set at a p value of <0.017 for comparisons among three groups (Bonferroni-Dunn correction). The Spearman correlation coefficient was used to test quantitative relationships between variables.

Results

There were no complications or reoperations between the 3.1 and 9.9-year follow-up examinations.

Clinical Results

At the time of the final follow-up, seventeen patients (74%) were very satisfied, five patients (22%) were satisfied, and one patient was disappointed. Between 3.1 and 9.9 years, the subjective result had not changed for seventeen patients, it had improved for five patients (two changed from satisfied to very satisfied and three changed from disappointed to very satisfied), and it had deteriorated for one patient (from very satisfied to satisfied).

Compared with an average subjective shoulder value of 80% (range, 50% to 100%) at 3.1 years, the average value at the time of the long-term follow-up remained unchanged at 82% (range, 45% to 100%; $p = 0.871$) and was comparable with that on the contralateral side (89%; range, 40% to 100%; $p = 0.119$). The relative Constant score, which had significantly increased from 51% preoperatively to 83% (range, 38% to 100%) at 3.1 years, averaged 85% (range, 22% to 100%) at 9.9 years. A significant positive correlation was detected between the subjective shoulder value and both Constant scores ($p = 0.0001$ and $r = -0.716$ for the absolute Constant score, and $r = 0.554$ and $p = 0.006$ for the relative Constant score). In the entire series, all tested clinical parameters improved significantly over the preoperative state with the exception of external rotation and strength of abduction. Between 3.1 and 9.9 years, the clinical parameters remained unchanged except for internal rotation. Details are depicted in Table I.

Comparison of Initial Two-Tendon and Three-Tendon Tears

Shoulders with a repaired two-tendon tear did not have significantly better results than the shoulders with a repaired three-tendon tear. The three-tendon tears, however, showed an overall greater functional improvement compared with the preoperative state than did the two-tendon tears. In the nine patients with a two-tendon tear that had been repaired successfully, the mean strength of abduction was 5.4 kg (range, 3.2 to 11.5 kg), the mean absolute Constant score was 80 points (range, 49 to 97 points), and the mean relative Constant score was 94% (range, 54% to 100%), whereas in the seven patients in whom the repair had retorn, the mean strength was 2.4 kg (range, 0 to 4.6 kg), the mean absolute Constant score was 67 points (range, 29 to 80 points), and the mean relative Constant score was 83% (range, 40% to 99%). Thus, the functional results of shoulders with an intact two-tendon repair were significantly better than those of the shoulders with a retorn repair ($p = 0.016$ for strength, $p = 0.042$ for absolute Constant score, and $p = 0.016$ for relative Constant score). For both two and three-tendon tears, the results with regard to the remaining parameters were not dependent on the integrity of the repair at the time of the latest follow-up.

Comparison of Initial Anterosuperior and Posterosuperior Tears

Anterosuperior and posterosuperior two-tendon tears yielded comparable final functional results. Conversely, patients with anterosuperior tears had a significantly greater gain in the Constant score ($p = 0.07$ for the absolute score and $p = 0.013$ for the relative score), pain score ($p = 0.005$), activities of daily living ($p = 0.008$), functional use of the arm ($p = 0.024$), and function ($p = 0.05$ for flexion and 0.038 for abduction) than did those with posterosuperior tears.

Comparison of Intact Repairs and Retears (Table II)

Compared with the ten (37%) of twenty-seven shoulders that had a retear at 3.1 years, thirteen (57%) of the twenty-three shoulders had a retorn rotator cuff at 9.9 years ($p = 0.168$). At both the 3.1-year and 9.9-year follow-up evaluations, no difference in age was found between the patients with and those without a retear. At the time of surgery, the patients with a retear at the 3.1-year evaluation had been an average of fifty-five years old (range, forty-seven to sixty-six years), and those with intact tendons had been an average of fifty-four years old (range, forty-two to sixty-seven years; $p = 0.769$). The respective ages for the patients reviewed at 9.9 years were fifty-four years (range, forty-two to sixty-seven years) and fifty-five years (range, forty-four to sixty-six years; $p = 0.593$). Only one of the four patients with a new retear noted between the 3.1 and 9.9-year evaluations reported another shoulder injury. In all thirteen patients with a retear, the Constant score had improved over the preoperative value and remained unchanged between the 3.1 and 9.9-year evaluations.

The male-to-female ratio of patients with an intact tendon and those with a retorn tendon remained unchanged between 3.1 and 9.9 years. Patients with a successful repair had significantly better absolute and relative Constant scores and strength than those with a failed repair (Table II). In patients with an intact repair, the results for those who initially had a two-tendon tear did not differ from those who initially had a three-tendon tear. The retear size at 9.9 years was found to have a significant negative correlation with the strength of abduction ($p = 0.0005$, $r = -0.564$) and the relative Constant score ($p = 0.0001$, $r = -0.672$) at 9.9 years.

Radiographic Results

Acromiohumeral Distance

The mean acromiohumeral distance decreased significantly ($p = 0.001$) from 9.4 mm (range, 4 to 14 mm) preoperatively to 7.8 mm (range, 3 to 15 mm) at 9.9 years. Five of the thirteen patients with a retear showed radiographic criteria of an irreparable tear[29]; two of the five patients initially had an anterosuperior two-tendon tear (supraspinatus and subscapularis), one patient had a posterosuperior two-tendon tear (supraspinatus and infraspinatus), and two patients had a three-tendon tear. A significant negative correlation was found between both the preoperative tear size ($p = 0.009$, $r = -0.581$) and the preoperative fatty infiltration of the infraspinatus muscle ($p = 0.01$, $r = -0.623$) and the acromiohumeral distance at 9.9 years. However, at 9.9 years, a significant negative correlation was found only between the degree of fatty infiltration of the supraspinatus muscle ($p = 0.042$, $r = -0.427$) and the acromiohumeral distance ($p = 0.127$, $r = -0.394$ for the infraspinatus, and $p = 0.864$, $r = 0.038$ for the subscapularis).

Glenohumeral Osteoarthritis

Between 3.1 and 9.9 years, the average severity of osteoarthritis increased from stage 1.3 to stage 2.0, according to the classification system of Samilson and Prieto[25] ($p = 0.0001$). At a mean of 9.9 years, fourteen of the twenty-three patients had stage-2 (five patients) or stage-3 (nine patients) osteoarthritic changes. At a mean of 3.1 years, eight patients had had stage-2 and none had had stage-3 osteoarthritis. Between the mid-term and long-term follow-up, six of them had had progression to stage-3 osteoarthritis.

Acromion Index

The acromion index was not significantly different in patients with an initial three-tendon tear (mean, 0.75; range, 0.66 to 0.88) than in patients with an initial two-tendon tear (mean, 0.68; range, 0.54 to 0.86; $p = 0.055$). The index was also not different between an initial anterosuperior tear and a posterosuperior tear ($p = 0.875$). A significant negative correlation was found between the acromion index and the preoperative Constant score ($p = 0.002$, $r = -0.672$).

The average acromion index in patients with an intact repair at the time of the latest follow-up was 0.65, which was significantly lower ($p = 0.004$) than that in patients with a retear (0.75) (Fig. 1). There was a significant, positive correlation between the size of the retear at 9.9 years and the acromion index ($p = 0.013$, $r = 0.509$).

Neither the patients with a retear nor those without a retear showed a decrease in the mean acromiohumeral dis-

TABLE II Comparison of Clinical Parameters of the Intact and Failed Reconstructions at 3.1 and 9.9 Years Postoperatively

	3.1-Yr Postop. (N = 27)			9.9-Yr Postop. (N = 23)			P Value for Difference Between 3.1 and 9.9 Yr	
	Intact	P Value*	Failure	Intact	P Value*	Failure	Intact Repair†	Failure†
No. of patients	17		10	10	0.37	13		
Male/female	10/7		8/2	5/5	0.19	10/3	0.65	0.75
Age† *(yr)*	56.8	0.51	56.2	64.9	0.61	63.5		
Follow-up† *(yr)*	3.1	0.40	3.1	10.0	0.31	9.8		
Subjective shoulder value† *(%)*	85.0	0.036	71.7	89.5	0.06	76.5	0.80	0.74
Constant score†§								
Absolute *(points)*	77	0.0112	59.6	81	0.015	64	0.08	0.21
Relative *(%)*	93.4	0.0077	70.6	95	0.002	77	0.27	0.21
Pain† *(points)*	13.4	0.64	12.1	13.3	0.27	12.1	0.31	0.95
Activities of daily living† *(points)*	9.8	0.08	8.4	9.3	0.08	8.2	0.59	0.56
Functional use of arm† *(points)*	9.47	0.11	7.6	9.8	0.44	8.8	0.83	0.70
Active mobility†								
Flexion *(deg)*	152.1	0.0038	124	154	0.45	136	0.71	0.16
Abduction *(deg)*	147.4	0.16	119	145.5	0.59	120	0.98	0.85
External rotation *(deg)*	45.8	0.16	32.5	46.5	0.25	36.2	0.67	0.70
Internal rotation#	7.5	0.91	7.2	9.0	0.10	7.7	0.042	0.021
Strength for abduction†** *(kg)*	3.94	0.003	1.39	5.5	0.007	2.6	0.10	0.16

*Mann-Whitney U test (the level of significance was a p value of <0.05). †With regard to the ratio of male to female patients, the value for the differences of intact repairs and those of failures between 3.1 and 9.9 years of follow-up was assessed with the Fisher exact test (the level of significance was a p value of <0.05). For the remaining parameters, the values for differences of intact repairs and failed repairs between 3.1 and 9.9 years of follow-up were assessed with the Mann-Whitney U test (the level of significance was a p value of <0.05). ‡The values are given as the average. §The absolute score is the average of the points given according to the system of Constant and Murley[18]. The relative Constant score is a percentage of an age and sex-related normal value[19]. #According to the system of Constant[18,19]. **Strength was measured with an Isobex dynamometer.

tance between the preoperative and the 3.1-year evaluations (10.8 to 10.6 mm for those with intact repairs [p = 1.0] and 8.6 to 8.2 mm for those with a retear [p = 0.862]). Conversely, between 3.1 and 9.9 years, the acromiohumeral distance decreased significantly in the retear group (from 8.2 to 6.8 mm; p = 0.015), whereas the decrease in this measurement in patients with an intact repair (10.6 to 9.1 mm) was not significant (p = 0.059). Progression of glenohumeral osteoarthritis was observed between 3.1 and 9.9 years in both groups (from 1.1 to 2.0 for those with an intact repair [p = 0.016] and from 1.5 to 2.0 for those with a retorn repair [p = 0.031]).

Magnetic Resonance Imaging

On magnetic resonance imaging, the tendons never appeared completely normal but were often somewhat irregular and had increased signals in comparison with normal rotator cuff tendons. When the humeral head was completely covered by tendon tissue inserting into the tuberosity, the repair was considered intact[28,30,31].

Retears

The retear rate after 9.9 years was 57% (thirteen of twenty-three shoulders). There was a trend to a higher retear rate in initial three-tendon tears (86%) compared with two-tendon tears (44%), but the difference was not significant (p = 0.068). With the small sample size investigated, the substantial difference in the 30% rate of retear for patients with an anterosuperior tear and the 67% rate for patients with a posterosuperior tear also did not reach significance (p = 0.168).

At the time of the final follow-up, none of the retears were larger than the initial tear. Compared with the retear size at 3.1 years, the average retear size had increased significantly from 882 to 1164 mm^2 (p = 0.016). Thirty-three percent of the retears documented at 3.1 years did not change in size between 3.1 and 9.9 years. No retear decreased in size or healed between 3.1 and 9.9 years. The size of the initial tear correlated positively with the retear size at 9.9 years (r = 0.512, p = 0.025).

Fatty Infiltration (Table III)

Whereas fatty infiltration significantly progressed between 3.1 and 9.9 years in the supraspinatus (p = 0.004) and infraspinatus muscles (p = 0.008), it did not progress in the subscapularis muscle (p = 0.055). At 9.9 years, there was significantly less progression of fatty infiltration in the supraspinatus muscles with an intact tendon (p = 0.004) than in those with a retear.

TABLE III Fatty Muscle Infiltration of the Rotator Cuff Muscles as a Function of the Integrity of the Tendons

	Preop.	3.1-Yr Postop.*			9.9-Yr Postop.*			P Value for Difference Between 3.1-Yr and 9.9-Yr Postop. Values in Entire Series†	P Values for Difference Between Preop. Intact and Torn Tendon Values at 9.9-Yr Postop.†
		Entire Series	Intact Preop.	Torn Preop.	Entire Series	Intact Preop.	Torn Preop.		
Supraspinatus									
Entire series	1.5	2.04		2.04	2.59		2.59	0.004	
Intact repair		1.79		1.79	1.85		1.85	0.99	
Failure	1.5	2.63		2.63	3.15		3.15	0.38	
P value for difference between intact repair and failure†		0.017		0.017	0.004		0.004		
Infraspinatus									
Entire series	1.74	2.09	1.70	2.47	2.65	1.90	3.23	0.008	0.0001
Intact repair	1.38	2.06	1.70	2.46	2.35	1.88	3.10	0.25	0.0040
Failure	2.06	2.5		2.5	3.05	2.00	3.31	0.31	0.07
P value for difference between intact repair and failure†	0.11	0.52		0.99	0.10	0.99	0.69		
Subscapularis									
Entire series	1.14	1.79	0.83	2.07	2.00	1.0	2.35	0.06	0.030
Intact repair	1.13	1.71	0.83	2.03	1.69	1.0	2.10	0.93	0.14
Failure	1.14	2.25	-	2.25	2.71	-	2.71	0.75	
P value for difference between intact repair and failure†	0.96	0.34		0.68	0.07		0.24		

*The values are given as the mean grade according to the system of Goutallier et al.[15,32]. †Mann-Whitney rank test (the level of significance was a p value of < 0.05).

Interestingly, the fatty infiltration increased significantly between 3.1 and 9.9 years only in the preoperatively torn infraspinatus (2.47 to 3.23; $p = 0.034$) and subscapularis muscles (2.07 to 2.35; $p = 0.031$). Compared with preoperatively intact tendons, the muscles of preoperatively torn infraspinatus or subscapularis musculotendinous units showed a significant increase ($p = 0.0001$ and $p = 0.030$) in fatty infiltration independent of the integrity of the repair at 9.9 years ($p = 0.685$ and $p = 0.235$, respectively). Whereas fatty infiltration of the supraspinatus muscle correlated negatively with strength ($p = 0.0004$, $r = -0.575$) and the relative Constant score ($p = 0.05$, $r = -0.413$) at 9.9 years, fatty infiltration of the infraspinatus did not ($p = 0.668$, $r = -0.094$ for strength and $p = 0.467$, $r = -0.160$ for relative Constant score). Interestingly, fatty infiltration not only of the supraspinatus muscle but also of the subscapularis muscle correlated negatively with strength of abduction ($p = 0.026$, $r = -0.464$). Patients with retears before the 3.1-year follow-up evaluation had a significantly higher grade of preoperative fatty infiltration[15,32] of the supraspinatus muscle (stage 1.9) than did patients in whom the tendon retore later (stage 1.0) ($p = 0.036$). The preoperative stages of fatty infiltration of both infraspinatus and subscapularis muscles were not different in early or late retears, with the small numbers studied.

Discussion

Open repair of massive rotator cuff tears with use of a currently accepted, open surgical technique yielded a moderate retear rate and good-to-excellent patient satisfaction and clinical results at the time of short-term follow-up[6]. Whether degenerative changes such as fatty infiltration persist, progress, or are reversible at the long term remains undetermined. Currently, specific factors that predict the retear potential of a reconstruction of a massive tear are largely unknown.

Compared with the 3.1-year follow-up evaluation, the clinical results remained unchanged at the 9.9-year evaluation in the same twenty-three patients studied. The average subjective shoulder value remained at 82% of a normal shoulder. The significant improvement over the preoperative state regarding pain, activities of daily living, function, and strength persisted, with an average relative Constant score of 85%. The correlations between the subjective shoulder value and both Constant scores were high and comparable with those in a previous study[23]. The differences between initial two-tendon

and three-tendon tears or between initial anterosuperior and posterosuperior tears disappeared. Despite a retear rate of 57%, 96% of the patients were either very satisfied or satisfied with the result. This is in agreement with other authors, who have reported that retears after open rotator cuff repairs can yield good-to-excellent long-term clinical results[9,20,21].

Various techniques have been described for rotator cuff reconstruction[8-11]. In this series, all repairs were performed with use of a transosseous repair technique that was tested in vitro and in vivo[6,12,13,20,21,33]. The postoperative structural integrity of the repaired tendons was determined with magnetic resonance imaging. Compared with a 13% rate of retears in isolated single-tendon tears[22], the retear rate of 57% at the time of the latest follow-up in this group is higher than, but comparable with, the results reported after the reconstruction of massive tears in other studies[8,9,34].

The functional outcome of a failed single-tendon repair is not inferior to that of an intact repair[22]. Conversely, failed massive rotator cuff repairs were functionally inferior to intact repairs in this series. This is consistent with the results seen by other authors[6,8,9,11], who have documented that successful repairs are associated with better functional results than are retears.

In this series, the clinical results at the time of the long-term follow-up in patients who had initially had a three-tendon tear did not differ significantly between intact and failed repairs. Conversely, retorn two-tendon repairs had significantly poorer functional results and strength than did intact two-tendon repairs. Even though the clinical results of retorn three-tendon repairs were worse than those of retorn two-tendon tears, this difference did not reach significance because of the low power of the study (one intact repair compared with six retears in the shoulders with three-tendon tears). However, compared with the preoperative state, the objective and subjective parameters improved in all patients with an initial three-tendon tear, even in the patients with a retear.

As opposed to other authors[35-37], we could not find a relationship between the age of the patients and the incidence of retears. This may be due to the relatively young age of the patients studied, as well as to the relatively small cohort size. Our data do not allow exclusion of an influence of age on the rate of healing of rotator cuff tears, but the data fail to confirm an influence within the studied cohort.

Consistent with other authors[20,21,38,39], we found that the acromiohumeral distance decreased in patients with a retear between the mid-term and long-term follow-up evaluation. Furthermore, the acromiohumeral distance at the time of final follow-up was negatively correlated to the preoperative tear size and the preoperative grade of fatty infiltration of the infraspinatus muscle. This may underline the importance and direct influence of the infraspinatus on the upward migration of the humeral head.

Neer described the influence of the shape of the acromion in the pathogenesis of an impingement syndrome[40]. Nyffeler et al.[26] analyzed the lateral extension of the acromion in patients with surgically documented rotator cuff disease. The patients with rotator cuff tears had a significantly larger lateral extension of the acromion than did patients without rotator cuff disease ($p = 0.0001$)[26]. Interestingly, in our series, the lateral extension of the acromion in patients with a retear was significantly larger than that of those without a retear ($p = 0.004$). Therefore, a large lateral extension of the acromion seems not only to be associated with degenerative tears[26] but also may be a risk factor for a retear after repair of a massive rotator cuff tear.

Interesting observations were made in terms of the evolution of the degenerative changes in the rotator cuff muscles. Even in the successful repair of a massive rotator cuff tear, fatty infiltration was irreversible at the time of the long-term follow-up. The fatty infiltration increased in the entire series in the supraspinatus and infraspinatus muscles and remained unchanged in the subscapularis muscle. Interestingly, if the infraspinatus and the subscapularis tendon had been initially ruptured, fatty infiltration increased over time. Therefore, the preoperative integrity of these tendons seems to determine the degree of fatty infiltration at long-term follow-up. Therefore, our findings suggest that rupture of a tendon is a trigger signal for the initiation or progression of fatty infiltration.

This study has limitations. Intraoperatively, anatomical refixation of the tendons back to the tuberosities was possible in all patients. With the postoperative imaging data from this study (staged magnetic resonance imaging examination after 3.1 and 9.9 years), we were not able to exactly determine the point in time of failure following repair. Therefore, a differentiation between nonhealing and retearing was not possible. The term *retear* used throughout this manuscript was not meant to necessarily imply healing prior to subsequent loss of tendon integrity. Rather, *retear* only denotes that a loss of tendon integrity was seen at some point after the initial operative repair. Because of the small number of patients investigated and the relatively young average age of the patients (fifty-four years), we could not make any correlations between age and structural integrity of the repair.

In conclusion, at an average of 9.9 years after repair of a massive rotator cuff tear, good and excellent clinical results are maintained. Attempts to repair a massive tear are still justified as patients fared better with regard to both function and strength, although the degree of clinical satisfaction was similar. Fatty muscle infiltration further increases even after successful repairs, especially in muscles in which the tendons were torn preoperatively. A high acromion index is associated with retearing, supporting the concept that wide lateral extension of the acromion is a risk factor for rotator cuff disease. ■

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