Clinical Outcome and Tendon Integrity of Arthroscopic Versus Mini-Open Supraspinatus Tendon Repair: A Magnetic Resonance Imaging–Controlled Matched-Pair Analysis

Dennis Liem, M.D., Christoph Bartl, M.D., Sven Lichtenberg, M.D., Petra Magosch, M.D., and Peter Habermeyer, M.D., Ph.D.

Purpose: Arthroscopic rotator cuff repair produces equally good clinical results compared with open or mini-open repair. However, there are concerns about whether the same repair integrity can be achieved. The purpose of our study was to compare clinical and structural results of arthroscopic and mini-open rotator cuff repair. **Methods:** Nineteen patients who had arthroscopic rotator cuff repair (mean follow-up, 25.0 months) were matched for age, gender, and duration of symptoms with nineteen patients who had mini-open repair (mean follow-up, 17.6 months). We compared preoperative and follow-up Constant scores, as well as early range of motion after 6 weeks and 3 months. All patients were examined with the same magnetic resonance imaging system at follow-up to evaluate cuff integrity. **Results:** There was no difference in clinical and structural outcome. The overall Constant score improved from 53.8 to 83.9 in the arthroscopic group and from 53.5 to 83.7 in the mini-open group. Early range of motion did not differ significantly at 6 weeks or 3 months postoperatively. The number of retears was 6 (31.6%) in the arthroscopic group and 7 (36.8%) in the mini-open group. This difference was not statistically significant ($P = .7358$). Although smaller retears had no influence on the clinical result, more retracted retears correlated with lower abduction strength regardless of the repair method. **Conclusions:** In isolated supraspinatus tears arthroscopic rotator cuff repair produces excellent clinical results and equivalent tendon integrity compared with mini-open repair. **Level of Evidence:** Level III, retrospective therapeutic comparative study. **Key Words:** Rotator cuff tear—Arthroscopic rotator cuff repair—Mini-open rotator cuff repair—Repair integrity.

In recent years arthroscopic rotator cuff repair has enjoyed increasing popularity among shoulder surgeons around the world. This development has been spurred by an increasing number of reports about good and excellent results of arthroscopic rotator cuff repair.[1-8] Comparison of these results with the well-established open and mini-open techniques has shown that arthroscopic repair can produce equally good results and high patient satisfaction.[9-14] Recently, some authors have directly compared the clinical results of open or mini-open repair against their arthroscopic repairs.[15-20] All found at least equally good results, and some even found more favorable results for the arthroscopic technique in some respects.[15,18,19]

So, although the clinical results of arthroscopic rotator cuff repair have been accepted almost unanimously as being as good as those of open repairs, the question of whether equivalent repair integrity can be achieved with the arthroscopic technique has been raised.[21] The subject of repair integrity for open rotator cuff repair has been addressed in the literature, and retear rates have been found to be between 25% and

From the Department of Orthopaedics, University Hospital of Muenster (D.L.), Muenster, and Shoulder and Elbow Service, ATOS-Clinic Heidelberg (C.B., S.L., P.M., P.H.), Heidelberg, Germany.

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Address correspondence and reprint requests to Dennis Liem, M.D., Department of Orthopaedics, University Hospital of Muenster, Albert Schweizer Strasse 33, 48149 Muenster, Germany. E-mail: dennisliem@web.de

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34% by several authors.[22-24] For arthroscopic rotator cuff repair, there are still only a limited number of studies that have analyzed clinical results and repair integrity.[1,25] The hypothesis of our study was that arthroscopic rotator cuff repair provides comparably good clinical results and equivalent repair integrity compared with mini-open repair.

METHODS

Patients and Selection Criteria

This retrospective study combines the results of 2 prospective studies with the same basic buildup. The inclusion criterion for both studies was an isolated supraspinatus tear confirmed by clinical examination and magnetic resonance imaging (MRI) that resulted in persistent pain and reduced function of the patient's arm. All patients had undergone unsuccessful conservative treatment that included physiotherapy, subacromial injections, and nonsteroidal anti-inflammatory medication. For both groups, exclusion criteria for the study were previous surgery, major trauma that involved dislocation or fracture, and concomitant adhesive capsulitis. Furthermore, patients were excluded if the tear extended to the infraspinatus or subscapularis or preoperative MRI revealed grade 3 atrophy of the supraspinatus according to the classification of Thomazeau et al.[26] or a high degree of fatty infiltration (greater than grade 2 according to Goutallier et al.[27]).

Informed written consent was acquired from the patients, who were educated on the nature of the prospective studies and informed that it included MRI examination at follow-up. This study was performed in private practice, and institutional review board approval was not considered necessary.

For the mini-open repair group, we found 24 consecutive patients who had mini-open rotator repair of an isolated supraspinatus tear between January 2000 and June 2001 and were prospectively followed up clinically and with MRI in our office as part of an earlier investigation. The minimum follow-up for this investigation was 12 months.

The arthroscopic group of patients was selected from a group of 53 consecutive patients operated on by the same surgical team between January 2002 and August 2003 who were also prospectively followed up clinically and on the same MRI system. The minimum follow-up for this investigation was 24 months.

Rather than simply comparing the data of those inhomogeneous groups, we decided to perform a matched-pair analysis to improve comparability. Matching was performed based on the following criteria: (1) age, (2) gender, and (3) duration of symptoms. Matching of the patient's age was performed so that the difference did not exceed 2 years. The duration of symptoms was matched based on 3 groups (<3 months, 3 to 12 months, and >12 months).

Overall, we were able to match 19 patients from each group who were comparable in all 3 criteria. Clinical data and MRI examination of these 2 groups were used for our comparison.

Clinical and MRI Examination

Clinical examination was performed prospectively in both groups. Patients were examined clinically and excluded from the study if they met one of the previously mentioned exclusion criteria. The selected patients underwent a standardized clinical examination preoperatively. Results were documented and evaluated by use of the Constant score, which includes the following parameters: pain, activities of daily living, range of motion, and abduction strength.[28] Abduction strength was measured with an Isobex dynamometer (Cursor, Bern, Switzerland). Patients were routinely examined 6 weeks and 3 months after surgery regarding complications and range-of-motion development.

At final follow-up, patients were invited to our office again to undergo a standardized clinical examination and evaluation by use of the Constant score. In addition, an MRI examination was performed at final follow-up in our office with the same open low-field system (0.2-Tesla E-Scan; Esaote, Genoa, Italy) by use of a shoulder coil. The MRI scans from both groups were examined in random order by 2 independent observers other than the operating surgeon, and cuff integrity was evaluated with established criteria.[29]

Operative Technique

All patients were operated on in the beach-chair position under general anesthesia. All procedures were started by a thorough diagnostic arthroscopy from a standard posterior portal to identify and address additional pathology (e.g., lesions of the biceps tendon or superior labrum). After this, the arthroscope was moved to the subacromial space and subacromial decompression consisting of bursectomy and acromioplasty without complete removal of the coracoacromial ligament was performed through an anterolateral approach. If necessary, an anterior portal was established to perform an arthroscopic resection of the acromioclavicular (AC) joint. A biceps tenotomy was performed arthroscopically through the anterolateral

portal with a meniscus punch. If there was a degenerative SLAP lesion, this was debrided with the shaver. The tear was then identified and prepared from the bursal side. The tear size was measured with a probe with a measuring scale on it. The largest diameter of a tear was measured after debridement of the avascular edges.

Mini-Open Repair Technique

In the mini-open group the arthroscope was removed and the anterolateral approach used for subacromial decompression was enlarged to 3 to 5 cm parallel to the deltoid fibers to minimize damage to the deltoid. The tear was again visualized, and the footprint was prepared for reinsertion of the tendon. The supraspinatus was repaired by use of 1 to 3 bioabsorbable suture anchors (Bio-Corkscrew FA; Arthrex, Naples, FL) armed with 2 pairs of nonabsorbable No. 2 sutures (Arthrex). Side-to-side FiberWire sutures were used if necessary. The tendon was sutured to the bone via the modified Mason-Allen technique with the combination of a U-shaped mattress suture and single suture on top of the mattress suture.

Arthroscopic Repair

In the arthroscopic group the procedure continued by establishing a posterolateral portal so that a 3-portal technique could be used for the repair. The arthroscope was moved to the posterolateral portal, and the supraspinatus tendon was released if necessary. The footprint was prepared with an acromionizer and a single row of 1 to 3 bioabsorbable suture anchors (Bio-Corkscrew FA) armed with 2 pairs of nonabsorbable No. 2 sutures that were placed along the lateral part of the footprint. According to the shape of the tendon, additional side-to-side sutures were used. The tendon was then repaired via a Mason-Allen technique modified for the arthroscopic technique.[30]

Postoperative Rehabilitation

The postoperative rehabilitation protocol was identical for both groups. The patient's arm is immobilized in a sling for 48 hours. When the patient has sufficiently recovered from the operation, the sling is changed to an abduction pillow holding the arm in approximately 20° abduction and 30° internal rotation for 3 weeks. Use of the pillow is gradually discontinued after 3 weeks. During the first 6 weeks, physiotherapy consisted of passive range-of-motion exercises for the shoulder. Range-of-motion limits were continuously increased from 60° abduction, 60° flexion, and 10° external rotation in week 1 to 90° abduction, 145° flexion, and 45° external rotation in week 6. Starting in week 7, free passive range of motion is allowed and active mobilization is begun. Starting in week 9, careful isometric strengthening exercises are begun, and the intensity of these exercises is increased to eccentric strengthening and weight-training in week 12.

Statistical Analysis

Statistical analysis was performed by use of SPSS statistical software (version 13.0; SPSS, Chicago, IL). The level of significance was set at .05. Preoperative and postoperative nonparametric data from both groups were analyzed with the Wilcoxon signed rank test. Comparisons between the 2 groups were performed by use of the Mann-Whitney *U* test.

RESULTS

Demographics

Because patients were matched for age, gender, and duration of symptoms, no significant differences were found for these parameters. Table 1 summarizes the demographic and intraoperative data of the 2 groups.

TABLE 1. *Demographic and Intraoperative Data*

	Arthroscopic Group (n = 19)	Mini-Open Repair Group (n = 19)
Age at surgery (yr)	61.9 ± 6.6	62.1 ± 6.7
Gender		
Male	16 (84.2%)	16 (84.2%)
Female	3 (15.8%)	3 (15.8%)
Duration of symptoms (mo)	10.6 ± 7.9	9.6 ± 5.2
Trauma	10 (52.6%)	6 (31.6%)
Follow-up (mo)	25.3 ± 1.3	17.5 ± 11.2
Tear size (Bateman classification[32])		
1	3 (15.8%)	1 (5.3%)
2	14 (73.7%)	15 (78.9%)
3	2 (10.5%)	3 (15.8%)
Arthroscopic subacromial decompression	19	18
AC joint resection	6	4
Biceps		
Complete tear	1	2
Tenodesis	0	2
Tenotomy	5	1
SLAP		
Degenerative	2	1
Repair	0	0
Complications	0	0

Table 2. *Preoperative and Postoperative Clinical Data*

	Arthroscopic Group (n = 19)			Mini-Open Repair Group (n = 19)		
	Preoperative	Postoperative	*P* Value	Preoperative	Postoperative	*P* Value
Constant score (points)						
Pain	6.2	14.3	.0001	6.7	14.4	.0001
ADL	10.0	19.1	.0001	12.5	19.4	.0001
ROM	31.2	37.9	.0017	26.7	37.6	.0003
Strength	6.4	12.6	.0002	7.6	12.3	.0019
Total	53.8	83.9	.0001	53.5	83.7	.0001
ROM (°)						
Flexion	155	176	.0061	154	175	.0110
Abduction	149	173	.0163	148	164	.2249
External rotation	47	59	.0107	52	56	.4297

Abbreviations: ADL, activities of daily living; ROM, range of motion.
NOTE. $P < .05$ indicates statistical significance.

Because there was a difference in minimum follow-up between the 2 groups (12 months in mini-open repair group and 24 months in arthroscopic group), the mean follow-up was significantly longer for the arthroscopic group.

There was a significant correlation between patient age and retear percentage. The retear rate was 41.7% in patients aged over 60 years compared with 21.4% in those aged 60 years or younger ($P = .009$).

Clinical Outcome

There was no difference regarding the clinical outcome between the mini-open repair group and arthroscopic group. Preoperative and postoperative Constant scores showed no differences. In both groups there was a significant improvement in all single parameters, as well as the overall Constant scores. The results are summarized in Table 2.

Additional procedures such as biceps tenotomy or tenodesis and AC joint resections did not influence the clinical outcome or the occurrence of retears.

Cuff Integrity

The number of identified retears was 6 (31.6%) in the arthroscopic group and 7 (36.8%) in the mini-open repair group. This difference was not statistically significant. The influence of cuff integrity on the clinical result was more obvious for the arthroscopic group. In both groups those patients with retears had lower abduction strength at follow-up. This difference was significant for the arthroscopic group but not for the mini-open repair group. Neither in the arthroscopic group nor in the mini-open repair group could a significant difference between intact repairs and return cuffs be observed. Cuff integrity did not have a significant influence on final range of motion at follow-up because no differences were observed between retears and intact repairs for either group (Table 3).

The retraction of the retear was assessed according to the Patte classification[31] on the coronal MRI scans. In the mini-open repair group 42.9% (n = 3) of the retears showed a grade 1 retraction as compared with only 1 case (16.7%) in the arthroscopic group. This group did not differ from the group of intact repairs in terms of clinical outcome. Higher degrees of retraction of the retear correlated with lower abduction strength. The influence on the overall Constant score was still below the significance level. The results of this analysis are summarized in Table 4.

Development of Range of Motion

Development of postoperative range of motion is summarized in Fig 1. Our results for flexion, abduction, and external rotation were slightly better in the arthroscopic group. These differences are not significant, however, either at 6 weeks, 3 months, or final follow-up. Statistical analysis of overall improvement showed significance for flexion ($P = .006$), abduction ($P = .016$), and external rotation ($P = .011$) in the arthroscopic group. In contrast, in the mini-open repair group significance was reached only for flexion ($P = .011$) but not for abduction ($P = .225$) or external rotation ($P = .430$) (Table 2).

During the first postoperative control examination after 6 weeks, 4 patients in the mini-open repair group showed signs of adhesive capsulitis and were treated with oral cortisone medication. In the arthroscopic

TABLE 3. *Postoperative Clinical Data: Retears Versus Intact Cuffs*

	Arthroscopic Group			Mini-Open Repair Group		
	Intact (n = 13)	Retear (n = 6)	*P* Value	Intact (n = 12)	Retear (n = 7)	*P* Value
Constant score (points)						
Pain	14.2	14.7	.6528	14.3	14.7	.6800
ADL	19.4	19.1	.8492	19.5	19.3	.7030
ROM	37.8	37.5	.8190	37.0	38.6	.2970
Strength	13.8	9.9	.0247	13.0	11.1	.2906
Total	85.2	81.2	.0584	83.8	83.7	.4990
ROM (°)						
Flexion	175	177	.5368	174	176	.7972
Abduction	167	172	.4439	163	166	.7528
External rotation	56	59	.2847	55	57	.6710

Abbreviations: ADL, activities of daily living; ROM, range of motion.
NOTE. $P < .05$ indicates statistical significance.

group this was found in 2 patients. This difference was not statistically significant ($P = .412$).

Preoperative Tear Size

Only isolated supraspinatus tears were included in this study. According to the classification of Bateman,[32] the mini-open repair group included 1 small, 15 medium, and 3 large tears. The arthroscopic group consisted of 3 small, 14 medium, and 2 large tears (Table 1). No significant influence on the clinical result or repair integrity was associated with the size of the tear. In addition, the size of the retear was not significantly influenced by the preoperative tear size.

DISCUSSION

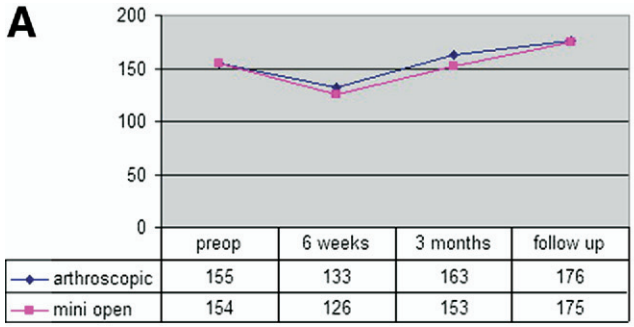
Rotator cuff repair seems to be on the verge of transitioning from an open repair to an all-arthroscopic repair.[33] The interest in arthroscopic rotator cuff repair has been rising immensely with the growing number of recent studies reporting excellent clinical results and high patient satisfaction.[1-8] As a result of the improvement in arthroscopic techniques and the availability of a large number of specifically designed instruments, more surgeons are willing to switch to all-arthroscopic repairs.

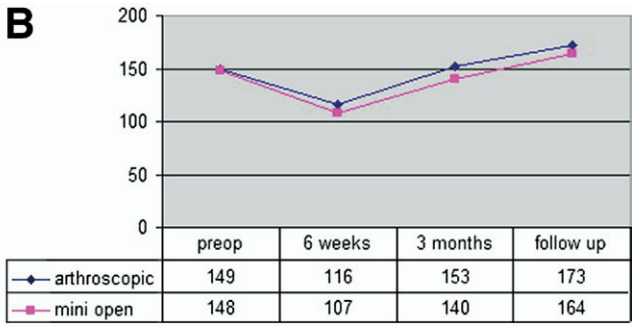
The hypothesis of this study was that arthroscopic supraspinatus repair produces clinical results and repair integrity comparable to mini-open repair. Overall, our results show that neither clinical results nor tendon integrity was different when we compared the arthroscopic technique with the mini-open repair technique. With regard to the clinical results, our findings are in agreement with the recent literature. Most authors did not find differences in clinical outcome between open and arthroscopic repairs. Warner et al.[16] compared a smaller number of matched patients without finding any significant difference in final outcome or patient satisfaction. They therefore concluded that the surgical approach should be chosen based on the surgeon's or patient's preference. Youm et al.[15] found no difference in University of California, Los Angeles's and

TABLE 4. *Retraction of Retears (Patte Classification[31]) and Their Influence on Clinical Outcome*

	No. of Patients (Arthroscopic/Mini-Open Repair)	Constant Score				
		Pain	ADL	ROM	Strength	Total
Intact cuff	25 (13/12)	14.6	19.4	37.8	13.8	85.6
Grade 1	4 (1/3)	14.8	19.3	37.5	13.6	85.2
Grade 2	6 (3/3)	14.7	19.3	37.0	9.8	80.8
Grade 3	3 (2/1)	14.7	18.4	38.7	6.7	78.5
P value		.966	.473	.723	.026	.100

Abbreviations: ADL, activities of daily living; ROM, range of motion.
NOTE. $P < .05$ indicates statistical significance.





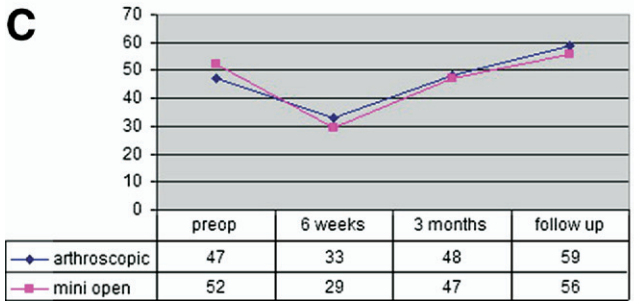


FIGURE 1. Progression of range of motion: (A) flexion, (B), abduction, and (C) external rotation.

American Shoulder and Elbow Surgeons' scores between their mini-open repair and arthroscopic groups. Patient satisfaction was equally high in both groups. The same can be said for Ide at al.[17] in their review of 100 cases. Clinical outcome was comparably good in both groups and was significantly influenced by tear size. No repair method was preferred for any tear size. One group of authors has even found favorable results at least in some respects for arthroscopic repair,[18,19] which has not been the case in our patients. Severud et al.[19] found better early range of motion for arthroscopic repairs at 6 and 12 weeks' follow-up. At final follow-up, there was no significant difference. They also found 4 patients with adhesive capsulitis in the mini-open repair group and none in the arthroscopic group. Clinical outcome measured with the University of California, Los Angeles's and American Shoulder and Elbow Surgeons' scores was equally excellent in both groups. Buess et al.[18] compared a larger number of patients and found better results for arthroscopic repair. In their series the arthroscopic group showed better pain relief, a higher score on the Simple Shoulder Test, and even higher subjective patient satisfaction regardless of tear size.

One of the potential clinical advantages of arthroscopic rotator cuff repair is faster recovery, especially with regard to early range of motion. We examined this aspect by monitoring range of motion at 6 weeks and 3 months postoperatively. In this respect the results of arthroscopic repair were not superior to those of mini-open repair. We found 4 patients with painful adhesive capsulitis in the mini-open repair group compared with 2 in the arthroscopic group. This difference was not statistically significant. At final follow-up, there were no differences in range of motion between the arthroscopic group and the mini-open repair group.

Additional procedures such as AC joint resection or tenotomy of the long head of the biceps did not have a statistically significant influence on the clinical and structural results. Two younger patients in the mini-open repair group (aged 45 years and 52 years) received a biceps tenodesis; all other patients with biceps pathology were aged at least 60 years and received a tenotomy.

Our study adds a detail that has not yet been addressed in the previously mentioned studies that have directly compared mini-open repair and arthroscopic repair, because it is MRI-controlled and can therefore address the issue of repair integrity. This has been a major concern with rotator cuff repair in general and especially with arthroscopic rotator cuff repair in comparison to open techniques. Several studies have documented the integrity of repaired cuffs to be between 25% and 96% for open and arthroscopic repairs.[1,21-25] Our results support the hypothesis that arthroscopic repair produces equal repair integrity compared with mini-open repair. For both mini-open repair and ar-

throscopic repair, the tendon integrity found in this study is comparable to that reported in the literature for isolated supraspinatus tears.

The influence of tendon integrity on the clinical outcome is not unanimously clear in recent studies, which is reflected in our findings. In the arthroscopic group the difference between retears and intact cuffs was significant for strength and just below the significance level for overall Constant score. In the mini-open repair group we found no difference in the results of retears versus intact cuffs. One reason for this is the higher number of small retears with a grade 1 retraction in the mini-open repair group. These patients had good and excellent Constant scores comparable to those of the group with an intact repair. One other explanation could be the shorter follow-up of the mini-open repair group. It could be hypothesized that results especially in the retear group will further deteriorate and, therefore, the influence on the clinical outcome will be more evident.

One important finding of this study is that the size of the retear had an influence on the clinical result. Regardless of the repair technique, our results indicate that small retears without much retraction do not lead to a substantial loss of abduction strength and cannot be differentiated clinically from intact repairs. When we compared the larger retears with at least a grade 2 retraction, there was a significant influence on the clinical result for both techniques regarding abduction strength. The other parameters of the Constant score were not influenced by the size of the retear. The size of the actual tear found intraoperatively had no influence on the clinical outcome or the size of the retear.

The repair technique used in our mini-open and arthroscopic repairs was a suture anchor technique in both cases. Most other studies comparing open and arthroscopic repairs have used a transosseous repair technique and have found no differences in clinical outcome. There is still controversy regarding suture anchor repair compared with a transosseous repair technique. Numerous studies have shown comparable or superior initial fixation strength for suture anchor repairs.[34-36] Other studies have shown superior contact pressure for the transosseous repair technique compared with a single row of suture anchors.[37,38] It could be argued that outcome and repair integrity would have been superior if a transosseous repair had been used. However, neither the clinical outcome nor the retear rate indicates that our mini-open repair technique has produced inferior results compared with the literature regarding transosseous repair.[22-24] The use of suture anchors in open rotator cuff repair is a viable repair method that is used in our clinic for open repair.

One major weakness of our investigation is that it is a retrospective analysis of prospectively acquired data. This issue remains unsolved in the literature, because prospective randomized studies with a control group are not available on this topic. The second issue is the low number of patients, especially compared with the other studies cited previously except for one.[15-20] We chose this approach of not including all patients available but carefully selecting matched pairs to achieve optimal comparability of the 2 groups. This helped to exclude confounding factors. We believed that sacrificing sample size by matching the patients would improve the comparability of the 2 groups.

In addition, there is a difference in follow-up between the mini-open repair group and the arthroscopic group. However, we believe that for the structural results, it does not make a difference because the hypothesis is that arthroscopic repair results in equal repair integrity. This is supported by the finding that there were fewer retears in the arthroscopic group (though not significantly) after a longer follow-up compared with the mini-open group after a shorter follow-up. The literature does not suggest that we could expect healing of the partly retracted retears. This means that a lower retear rate could not have been expected if the follow-up of the mini-open repair group had been longer. However, there have been reports showing that, for arthroscopic repair of massive rotator cuff tears, clinical results have deteriorated after 2 years compared with 1 year.[21]

CONCLUSIONS

Our hypothesis that arthroscopic supraspinatus repair leads to equally good clinical and structural results compared with mini-open repair was confirmed in this study. The results regarding early range of motion and postoperative frozen shoulder were not superior for arthroscopic repair. Tendon integrity only had an influence on the clinical result if the retear was more retracted. If this was the case, patients showed lower abduction strength, whereas the other parameters of the Constant score were not influenced by the presence of a retear.

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