The temporal outcomes of open versus arthroscopic knotted and knotless rotator cuff repair over 5 years

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Abstract

Background: The present study aimed to determine how repair technique influenced structural and clinical outcomes at 5 years post-surgery.

Methods: Three cohorts of patients had repair of a symptomatic rotator cuff tear using (i) an open double-row mattress repair technique ($n = 25$); (ii) arthroscopic single-row simple suture knotted technique ($n = 25$); or (iii) arthroscopic single-row inverted mattress knotless technique ($n = 36$) by one surgeon. Standardized patient- and examiner-determined outcomes were obtained pre-operatively and postoperatively with a validated protocol, ultrasound were also performed at the same time.

Results: Retear occurred more often after open repair (48%) at 5 years than after arthroscopic knotted (33%) and arthroscopic knotless (26%) repair. Retear was associated with increasing age, pre-operative tear size and weaker pre-operative and 5 years postoperative cuff strength. Between 2 years and 5 years, the open repair group experienced an increase in the frequency of pain during activity, as well as in the difficulty experienced and the severity of pain during overhead activities ($p < 0.05$) and, at 5 years, also experienced more difficulty with overhead activities, compared to the arthroscopic knotless repair group.

Conclusions: At 5-year follow-up, arthroscopic rotator cuff repair techniques resulted in fewer retears and better outcomes compared to an open double-row technique.

Keywords

Arthroscopic surgery, mini-open surgery, retear rate, rotator cuff, shoulder

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Introduction

Rotator cuff tears are common, occurring in 30% to 54% of people aged over 60 years.^{1–3} The supraspinatus tendon is the most frequently torn.⁴ Rotator cuff tear is often associated with shoulder pain, weakness and stiffness and a reduction in an individual's ability to perform activities of daily living and many occupational roles.¹

Rotator cuff repair (RCR) aims to restore shoulder function by reattaching the torn tendon back to the humeral head. The surgery was first performed using open techniques; however, advancements in arthroscopy facilitated less invasive repair methods, helping RCR evolve from open to all-arthroscopic techniques.

Rotator cuff retear is the most significant complication post-surgery. Estimates of the rate of retear range greatly from 15% to 90% after RCR.^{5–9} Although there have been investigations into repair integrity up

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to 2 years postoperatively, there is a lack of data on longer-term outcomes of more than 2 years for open versus arthroscopic RCR.

Our institute had previously conducted a 2-year follow-up study of three types of RCR, and this same cohort of patients is now 5 years post-surgery. The primary aim of the present study was to determine how repair technique affected rotator cuff integrity at 5 years post-surgery. The secondary aim was to assess how these techniques influenced postoperative strength, passive range of motion and patient-ranked pain scores, and to determine whether there has been any deterioration or improvement in these outcomes at 2-year follow-up.

Materials and methods

Study design and patient selection

The present study was a retrospective study of prospectively collected data. It was conducted with ethics approval by the South Eastern Sydney and Illawarra Ethics Committee (HREC LNR/12/STG/106). Informed consent was obtained from all participants.

Between July 2002 and March 2006, the senior author (GACM) performed RCR on 312 consecutive patients. From July 2002, he performed RCR surgery with an open technique and then, from December 2003, he transitioned towards an arthroscopic knotted technique; basing his decision whether or not to perform arthroscopic repair on the size of the tear, as well as his increasing experience with the arthroscopic procedure. From August 2005, the surgeon changed to an arthroscopic knotless technique. Patients were recruited based on the previous follow-up study by Millar et al.¹⁰ that compared the open technique with the two arthroscopic methods at 2 years.

To qualify for inclusion into the study, patients must have (i) undergone RCR following symptomatic full-thickness supraspinatus tears (or partial thickness supraspinatus tears converted intra-operatively to full-thickness tears) and (ii) returned for examination and ultrasound at 6 months post-surgery. It is the surgeon's practice that all partial thickness tears involving greater than 50% of the thickness of the tendon were converted intra-operatively to full-thickness tears before repair. Those less than 50% were managed without surgery.

Patients with (i) glenohumeral arthritis, (ii) fracture, (iii) previous shoulder surgery, (iv) osteonecrosis, (v) partial-thickness rotator cuff tears, (vi) a history of surgery within the first 6 weeks of the surgeon changing to arthroscopic techniques or (7) who were unable or unwilling to undergo ultrasound examination at 6 months and 5 years postoperatively were excluded.

For the present study, 159 patients who satisfied the inclusion criteria were invited to return for a

5-year follow-up. Patients who were unable to attend the follow-up or complete a Shoulder Service Questionnaire at least 5 years post-surgery were excluded from the study.

RCR techniques

All three RCR techniques were performed as day-case surgery under interscalene block. The patient was seated in the upright beach chair position and given a pre-operative dose of the same antibiotic (1 g of cefazolin intravenously) and one additional dose of this antibiotic 4 h postoperatively. Operative time was defined as the time in minutes from first skin incision until wound closure.

Open repair technique. The open RCR technique was performed using a double-row anchor technique as described by previously Cummins et al.¹¹ It involved partial splitting of the deltoid parallel with its fibres, temporary detachment of the coracoacromial ligament, anterior acromioplasty and bursectomy. Before repair of the cuff, soft tissue releases were performed where appropriate to minimize tension on the repair. Mitek RC Quickanchor (Depuy Orthopaedics Inc., Warsaw, IN, USA) suture anchors were impacted directly into the proximal humerus. The torn tendon was clasped in a horizontal mattress construct by #2 braided, nonabsorbable polyester suture or #2 absorbable Panacryl sutures (Ethicon Inc., Somerville, NJ, USA). A double-row technique was used in all repairs where there was adequate excursion of the torn tendon.

Arthroscopic repair techniques. Arthroscopic RCR was performed using the standard three-portal technique as described by Gartsman and Hammerman.¹² After initial glenohumeral joint inspection, the arthroscope was directed into the subacromial space where acromioplasty was then performed. Any adhesions that had formed between the torn cuff and its surrounding tissues were released to maximize cuff mobility and minimize tension on the repair. This enabled all cuffs to be repaired directly to the lateral-most aspect of the greater tuberosity at zero degrees of abduction without medialization. An arthroscopic burr was then used to prepare both the torn cuff edge and a cancellous bed at the repair site (footprint) on the greater tuberosity.

Arthroscopic knotted repair was performed using a single-row technique with two simple sutures per 5-mm Mitek Fastin metal double-suture loaded corkscrew anchor (Depuy Orthopaedics Inc.). The anchors were inserted through the lateral accessory portal and impacted in a single anterior-posterior row into the footprint on the lateral-most margin of the greater tuberosity. Sutures were passed through the tendon

evenly spaced and 5 mm from the torn edge and then secured with five knots.

Arthroscopic knotless repair was performed using a single-row inverted mattress (tension band) technique. Working through the lateral portal, the Opus SmartStitch Suture Device (ArthroCare Corp, Austin, TX, USA) was used to drive a #2 polyester mattress suture through the torn tendon. A hole for the anchor was punched into the corresponding position on the footprint. Both limbs of the suture were passed through the Opus Magnum Knotless Implant and the anchor and suture construct implanted together into the prepared hole. The tendon was reduced to bone by winding and locking the suture into the anchor.

Postoperative rehabilitation

For the initial 6 weeks after surgery, patients in the open group wore a shoulder sling and patients in the arthroscopic groups wore a sling with a small abduction pillow (Ultrasling; DJO Global, Vista, CA, USA). They began a gradually progressive home rehabilitation program as described by Hayes et al.¹³ The programme began with pendulum exercises. After the first postoperative visit at day 8, the patients began passive forward flexion, external rotation, and abduction range of motion exercises. Active range of motion and simple isometric strengthening exercises were initiated at the 6-week postoperative visit. Active overhead activities and lifting 5 kg or more usually began 3 months postoperatively.

Outcome measures

Standardized examiner-determined and patient-determined outcomes were obtained pre-operatively and at 6 weeks, 3 months, 6 months, 2 years and 5 years postoperatively.

Rotator cuff retear rate determination. Rotator cuff integrity was used as the primary outcome measure and was determined pre-operatively and at six months, 2 years and 5 years postoperatively via ultrasound. Bryant et al.¹⁴ has validated ultrasound study as an accurate measure of pre-operative rotator cuff tear size, and all imaging was performed following a standardized protocol.

Imaging was performed by six experienced musculoskeletal sonographers at pre-operative, 6-month and 2-year time points using either an Acuson 128XP or Sequoia machine (Acuson Corp., Mountain View, CA, USA) with a 7.5-MHz to 12-MHz linear transducer or a General Electric Logiq (GE Corp., Fairfield, CT, USA) with a 12-MHz linear transducer. Imaging was performed by a single experienced

musculoskeletal sonographer (LB) at 5-year follow-up using a General Electric Logiq E9 (GE Corp.) with a linear ML6 to 15-MHz transducer.

Supraspinatus integrity was assessed with the shoulder adducted and extended, the elbow flexed to 90° and the hand supinated allowing for maximum visualization underneath the acromium. The ultrasound probe was orientated parallel to the tendon fibres to allow examination in the longitudinal plane. The entire length of the tendon was observed by repositioning the transducer anteriorly, posteriorly, medially and laterally and measurement of tendon defects was taken in both the anterior–posterior plane and the medial–lateral plane to calculate defect size in centimetres squared. The biceps tendon was observed in both short and long axis, and the subscapularis tendon was observed with the arm in external rotation. All findings were reported on a standardized ultrasound assessment form.

Intra-operative data. Intra-operative information was recorded on standardized operative report forms as described previously by Bryant et al.¹⁴ This included visual estimation of cuff tear size, the number and type of anchors used, additional procedures performed and the condition of the tendon.

Functional testing. Clinical testing was performed by a blinded independent observer. Passive range of motion for forward flexion, abduction, external rotation and internal rotation were measured by visual estimation, which has been demonstrated to have fair-to-good reliability compared to other methods.¹⁵ Quantitative strength measurements of the shoulder for internal rotation, external rotation, abduction in the scapular plane (supraspinatus), abduction and lift off were taken using a Handheld Force Gauge (HGF-110; Transducer Techniques, Temecula, CA, USA) which has been found to be the most reliable and discriminatory means of assessing shoulder strength.^{16,17} Rotator cuff functional index (RFI) was derived from these measurements as described by Osbahr and Murrell.¹⁸

Patient-ranked pain scores. At each visit (first and each subsequent visit after RCR), patients completed a modified L'Insalata questionnaire¹⁹ with Likert scale that required them to rate their: (i) frequency of shoulder pain with activity and during sleep and frequency of extreme pain (always, daily, weekly, monthly, never); (ii) severity of pain at rest, during overhead activities and during sleep (very severe, severe, moderate, mild, none); (iii) level of shoulder stiffness (very severe, severe, moderate, mild, none); (iv) difficulty reaching behind back and with overhead activities (very severe,

severe, moderate, mild, none); and (v) overall condition of the shoulder (very bad, bad, poor, fair, good).

Statistical analysis

Dichotomous data such as cuff retear rate and patient demographics were analyzed using chi-squared analysis with Yate's correction. For parametric data such as tear size, range of motion and shoulder strength, an unpaired Student's *t*-test was used to assess differences between the groups at specific time points, and a paired Student's *t*-test to assess differences between different time points within each group. For nonparametric data such as patient-ranked pain scores and internal rotation, one-way analysis of variance (ANOVA) with Bonferroni adjustments (Dunn's method) was used to assess differences between the three groups at specific time points, and a Wilcoxon signed-rank test was applied to assess differences between different time points within each group. Two-way ANOVA with Bonferroni adjustments was used to assess the influence of time and repair technique to differences among the groups. Nonparametric correlations were analyzed using Spearman's correlation coefficient. Parametric correlations were analyzed using Pearson's correlation coefficient. Statistical analysis was performed using Prism, version 5.00 (GraphPad Software Inc., San Diego, CA, USA) and SPSS, version 20 (IBM Corp., Armonk, NY, USA).

Results

Demographics and intra-operative data

For the present study, 159 patients who satisfied the inclusion criteria were invited 5 years post-surgery for follow-up. Seventy-three patients were excluded as because they did not attend the follow-up. A further 16 patients could not attend the follow-up clinic and were thus not included in the ultrasound and examination investigations having only completed the patient-ranked pain questionnaire. This left 70 patients for ultrasound, range of motion and strength evaluations and 86 patients for patient ranked pain questionnaire at 5-year follow-up.

At 5-year follow-up, there were 13 men and 12 women in the open group with an average age of 59 years (range 43 years to 74 years), 10 men and 15 women in the arthroscopic knotted group with an average age of 62 years (range 40 years to 80 years) and 19 men and 17 women in the arthroscopic knotted group with an average age of 60 years (range 38 years to 86 years). The average duration from initial injury to surgical repair was 554 days (range 15 days to 2477 days) for the open group, 217 days (range 24 days to 1116

days) for the arthroscopic knotted group and 231 days (range 39 days to 1092 days) for the arthroscopic knotless group. The open repair group had a significantly longer duration from initial injury to surgical repair ($p < 0.05$) compared to the two arthroscopic groups (Table 1).

A greater ratio of left to right shoulder repair ($p < 0.05$) was performed in the open group (44%) compared to the knotted group (24%) and knotless group (25%); however, the percentage of dominant arms repaired was similar among the groups. The percentage of work related rotator cuff injury was not different among the groups.

Average pre-operative tear sizes were similar among the groups: 4.4 cm^2 (range 1.0 cm^2 to 14 cm^2), 4.0 cm^2 (range 1.0 cm^2 to 13.5 cm^2) and 4.0 cm^2 (range 1.0 cm^2 to 15.8 cm^2) in the open, knotted and knotless groups, respectively.

The open repair group was repaired with a significantly greater number of anchors (average of 4.1) for fixation than in the knotted group (average of 2.0) and the knotless group (average of 2.6), consistent with a two-row technique in the open surgery group ($p < 0.0001$). The arthroscopic knotless group used significantly more anchors ($p < 0.01$) than the knotted group.

There was no significant difference in operation time between open (average 57 minutes) and arthroscopic knotted cuff repairs (average 53 minutes). Operative time for arthroscopic knotless repair (average 42 minutes) was significantly shorter compared to open cuff repair ($p < 0.001$) and arthroscopic knotted repair ($p < 0.01$).

Primary outcome

Postoperative retear rate. The retear rate of the entire cohort as detected by ultrasound at 5 years was 34% (24 of the 70 shoulders). Five years post-surgery, the open repair group had a significantly higher retear rate (48%; 10 of 21) compared to the arthroscopic knotted (33%, six of 18; $p < 0.05$) and arthroscopic knotless (26%, eight of 31; $p < 0.01$) repair groups. There was no statistically significant difference in retear sizes at 5 years among the three repair groups: open repair 7.0 cm^2 (range 1 cm^2 to 12.7 cm^2), arthroscopic knotted repair 4.1 cm^2 (range 0.8 cm^2 to 9.3 cm^2) and arthroscopic knotless repair 4.3 cm^2 (range 0.1 cm^2 to 9.9 cm^2) See Figure 1.

The retear rate of the arthroscopic knotted repair group increased from 20% to 33% between 6-month and 5-year follow-ups ($p = 0.05$). At 5 years post-surgery, the retear rate of the open repair group remained unchanged from the 6-month level (48%), and the arthroscopic knotless repair group increased

Table 1. Demographics of patients in the groups.

Variable	Open	Knotted arthroscopic	Knottedless arthroscopic	Open versus arthroscopic knotted	Open versus arthroscopic knottedless	Arthroscopic knotted versus arthroscopic knottedless
Number of patients	25	25	36			
Male : Female*	13 : 12	10 : 15	19 : 17	NS	NS	NS
Age at surgery (years) ^{†‡}	59 (43–74)	62 (40–80)	60 (38–86)	NS	NS	NS
Time from initial injury to repair (days) ^{†‡}	554 (15–2477)	217 (24–1116)	231 (39–1092)	$p < 0.05$	$p < 0.05$	NS
Affected shoulder						
Left : right*	11 : 14	6 : 19	9 : 27	$p < 0.01$	$p < 0.01$	NS
Dominant hand*	18	19	25	NS	NS	NS
Work related injury*	5	4	8	NS	NS	NS
Pre-operative tear size (cm ²) ^{†‡}	4.4 (0.8) (1.0–14.0)	4.0 (0.8) (1.0–13.5)	4.0 (0.6) (1.0–15.8)	NS	NS	NS
Number of anchors used ^{†§}	4.1 (0.3) (2–8)	2.0 (0.1) (1–4)	2.6 (0.1) (2–4)	$p < 0.0001$	$p < 0.0001$	$p < 0.01$
Operation time (minutes) ^{†‡}	57 (35–100)	53 (30–80)	42 (25–60)	NS	$p < 0.001$	$p < 0.01$

*Comparisons between groups using chi-squared analysis with Yate's correction. †Comparisons between groups using Student's t-test. ‡Values expressed as the mean (SEM), followed by the range. §Values expressed as the mean (SEM), followed by the range. NS, no significance.

from 19% to 26%; however, this difference did not achieve significance.

Size of pre-operative versus postoperative tear at 5 years. There was a strong correlation between pre-operative tear size and retear size at 5 years in the open repair group ($r=0.55$, $p=0.05$); however, the arthroscopic knotted ($r=0.72$, $p=0.06$) and arthroscopic knotless ($r=0.47$, $p=0.12$) RCR groups did not show the same relationship.

Secondary outcomes

Passive range of motion. Five years postoperatively, all repair groups showed significant improvement in range of motion for forward flexion, abduction and external rotation compared to pre-operative levels, whereas no group showed significant improvement in internal rotation compared to pre-operative levels

($p < 0.05$). Two-way ANOVA showed that forward flexion had improved significantly more in the arthroscopic knotted repair group (36%) compared to the open (16%) and arthroscopic knotless (11%) repair groups ($p < 0.01$).

Range of motion between 2-year and 5-year follow-ups improved significantly for forward flexion in the open repair group ($p < 0.01$), abduction in the open and arthroscopic knotless repair groups ($p < 0.05$), internal rotation in the open and arthroscopic knotted repair groups ($p < 0.05$) and external rotation in all three repair groups ($p < 0.01$).

Shoulder strength and RFI. At 5-year follow-up, the arthroscopic knotless repair group had significantly greater external rotation strength compared to both open and arthroscopic knotted repair groups ($p < 0.05$) (Figure. 2). Multiple logistic regression analysis showed that patient's age was the only significant

Figure 1. Intact and return rotator cuff repairs at 5 years post-surgery according to pre-operative tear size in (A) open ($n = 21$), (B) arthroscopic knotted ($n = 18$) and (C) arthroscopic knotless ($n = 31$) rotator cuff repairs.

factor to influence strength with external rotation at 5 years after surgery. Five years postoperatively, only the arthroscopic knotted and knotless groups showed significant improvement in strength for abduction in the scapular plane ($p < 0.01$), external rotation ($p < 0.01$) and internal rotation ($p < 0.05$) compared to pre-operative levels (Figures 2 and 3). Two-way ANOVA shows that the arthroscopic knotted technique significantly influenced the improvement in supraspinatus strength between pre-operative and 5-year time points compared to the arthroscopic knotless repair group ($p = 0.05$). The arthroscopic knotless repair group had significantly greater internal rotation strength compared to the arthroscopic knotted group before surgery, at 6 months and 3 years after surgery. All groups showed significant improvement in lift-off strength, whereas only the arthroscopic knotless group showed improvement in RFI ($p < 0.05$) and no group showed significant improvement in adduction strength. The arthroscopic knotted repair group showed a significant reduction in lift-off strength of 19% between 2-year and 5-year follow-up visits ($p < 0.01$).

Patient-ranked pain scores. At 5 years post-surgery, each repair group showed significant improvement in all patient ranked pain and function scores compared to pre-operative levels ($p < 0.01$); however, between 2-year

and 5-year follow-ups, the open group showed a significant increase in the frequency of pain during activity and the severity of pain and difficulty experienced during overhead activities ($p < 0.05$) (Figures 4, 5 and 6).

At 5-year follow-up, the arthroscopic knotless repair group experienced less difficulty with overhead activities than the open repair group. Two-way ANOVA found that repair technique was not a contributing factor at decreasing pain severity during overhead activities or decreases in difficulty with overhead activities between pre-operative levels and 5-year follow-up. Multiple logistic regression analysis showed the number of anchors used during surgery was a major contributing factor in postoperative patient ranked difficulty with overhead activity.

Discussion

The present study found that, at 5 years post-surgery, the patients who had arthroscopic knotted and arthroscopic knotless RCR had more intact repairs than the open repair technique. The open repair group also experienced no improvement in strength at 5-year follow-up compared to pre-operative levels and patient-ranked pain and shoulder function scores deteriorated from 2-year follow-up. The arthroscopic knotless repair group had greater external rotation strength

Figure 2. External rotation strength for open, arthroscopic knotted and arthroscopic knotless rotator cuff repair; ** $p < 0.01$ between pre-operative examination and 5-year follow-up using paired Student's *t*-test; † $p < 0.05$, †† $p < 0.01$ comparing *b* = open versus arthroscopic knotless and *c* = knotted versus knotless arthroscopic using unpaired Student's *t*-test; overhead lines denote statistical significance between time points for their respective repair groups.

Figure 3. Strength of abduction in the scapular plane for open, arthroscopic knotted and arthroscopic knotless rotator cuff repair; $^{**}p < 0.01$ between pre-operative examination and 5-year follow-up using paired Student's *t*-test; $^{\dagger}p < 0.05$ comparing *a* = open versus arthroscopic knotted and *c* = knotted versus knotless arthroscopic using unpaired Student's *t*-test; overhead lines denote statistical significance between time points for their respective repair groups.

Figure 4. Patient-ranked overall shoulder function for open, arthroscopic knotted and arthroscopic knotless rotator cuff repair; $^{***}p < 0.001$, $^{****}p < 0.0001$ between pre-operative examination and 5-year follow-up using Wilcoxon signed-rank test; overhead lines denote statistical significance between time points for their respective repair groups.

Figure 5. Pain severity during overhead activity for open, arthroscopic knotted and arthroscopic knotless repair; * $p < 0.05$, ** $p < 0.01$, **** $p < 0.0001$ between pre-operative examination and 5-year follow-up using Wilcoxon signed-rank test. † $p < 0.05$ comparing a = open versus arthroscopic knotted and c = knotted versus knotless arthroscopic using one-way ANOVA with Bonferroni adjustments; overhead lines denote statistical significance between time points for their respective repair groups.

Figure 6. Difficulty with overhead activity for open, arthroscopic knotted and arthroscopic knotless rotator cuff repair; * $p < 0.05$, ** $p < 0.01$, **** $p < 0.0001$ between pre-operative examination and 5-year follow-up using Wilcoxon signed-rank test. † $p = 0.05$, † $p < 0.05$ comparing a = open versus arthroscopic knotted and b = open versus knotless arthroscopic using one-way ANOVA with Bonferroni adjustments; overhead lines denote statistical significance between time points for their respective repair groups.

at 5 years compared to both other groups, and was the only repair group to improve in rotator cuff functional index.

A number of biomechanical studies have shown double-row constructs to have higher load to failure than single-row techniques at time zero,^{20–24} and a systematic review by Duquin et al.²⁵ found double-row techniques to correlate with lower retear rates compared to single-row techniques. In the present study, however, a double-row repair technique did not translate to a lower rate of retear at 5-year follow-up, with retear occurring more frequently after open repair (48%) than after arthroscopic knotted (33%) or arthroscopic knotless (26%) repair. This could be a result of their less invasive nature or anchor-suture configuration. It could also be a result of a significantly greater delay in surgery in the open group (554 days) compared to arthroscopic groups (217 days to 231 days), although, in the present study, no significant correlation was found between patient retear rate and a longer duration from initial injury to surgery. Another consideration is the fact that, throughout the first 6 weeks of postoperative care, the open group wore only a regular sling whereas the arthroscopic groups also wore an abduction pillow.

Matthew et al.²⁶ has shown small rotator cuff tears to have the greatest healing potential as a result of increased fibroblast cellularity and inflammatory cells, whereas larger tears may have highly degenerate tissue and hence a decreased ability to repair and regenerate. This hypothesis was supported by our results; at 5 years post-surgery, only 18% (eight of 44) of tears less than or equal to 3 cm² retear compared to 62% (16 of 26) of tears greater than 3 cm². One important note, however, was that massive tears (>5 cm²) repaired with the arthroscopic knotless technique had significantly lower retear rate at 6 months and 5 years post-surgery than both open and arthroscopic knotted repairs. This outcome could have been influenced by the fact that the surgeon began implementing the knotless procedure 30 months after first performing arthroscopic repairs, which may contribute to better technique and shorter operative time. Another contributing factor could lie in the inverted-mattress configuration of the arthroscopic knotless repair. Using an animal model, Andres et al.²⁷ found that inverted-mattress (tension-band) constructs had significantly higher footprint contact pressure compared to single and double-row repairs, and this compression force was found to increase as increasing tension was applied to the repair. It may be that a higher footprint contact pressure is more important than a higher load to failure for promoting healing in massive tears, and hence the lower retear rate for arthroscopic knotless repairs compared to open and arthroscopic knotted repairs.

Our results support studies showing that increasing age and large pre-operative tear sizes are negative prognostic factors with respect to cuff integrity following repair.^{5,9} Although weak pre-operative strength measurements correlated well with return cuffs at 5 years, we found no associations between retear rate and the dominant shoulder, duration of symptoms, pre-operative and 5-year range of motion or pre-operative rotator cuff functional index. Although temporal analysis between 6-month and 5-year follow-ups found no significant increase in the retear rates of the open and arthroscopic knotless repair groups, it identified a significant increase in the retear rate of the arthroscopic knotted repair group ($p=0.05$), which raises questions regarding the durability of this particular type of repair and suggests that the early structural integrity of the cuff may not be an accurate indicator of long-term outcome.

Good clinical outcomes using either open or arthroscopic RCR techniques are well documented,^{28–32} and observer and patient ranked outcomes for open and arthroscopic repair appear to be similar up to 2-year follow-up.^{25,33–38} We found that, at 5 years post-surgery, the arthroscopic knotless technique produced greater strength in external rotation than both open and arthroscopic knotted repairs, and was the only technique to show a significant increase in the rotator cuff functional index compared to pre-operative level. Between the pre-operative examination and 5-year follow-up, the open repair group did not improve in any plane of shoulder strength measurement except lift off, whereas both arthroscopic knotted and arthroscopic knotless repairs improved in all modes of strength except adduction; corresponding with its purpose as the examinations internal control.³⁹ Between 2-year and 5-year postoperative visits, the open repair group also showed an increase in difficulty reaching overhead, pain experienced during shoulder activity, and pain severity during overhead activities. All patient-ranked pain scores and ranges of motion (apart from internal rotation) improved significantly for the three groups between pre-operative and 5-year time points.

The limitations of the present study include the study design. The groups were three temporal cohorts rather than randomized groups, and the study had a sample size of only 86 patients. The variance between the groups from the time of original surgery to the follow-up visit could have influenced the retear rate. The shift in practice toward arthroscopic techniques may have changed surgical indications and postoperative regimes. At pre-operative, 6-month and 2-year follow-ups, imaging was performed by one of six sonographers. The different postoperative sling constructs between open and arthroscopic groups may contribute

to differences observed among the groups. The present study reflects the experience of a single surgeon and thus the conclusions cannot be extrapolated to practise in general. The strength of the study included the well-established follow-up protocol with the long-term minimum 5-year follow-up. To our knowledge, this is the first 5-year follow-up study comparing open and arthroscopic RCR techniques that has been conducted.

Conclusions

The results of the present study showed that RCR performed as an arthroscopic knotted single-row or arthroscopic knotless single-row inverted mattress technique resulted in a significantly lower retear rate at 5 years compared to an open double-row technique. At 5-year follow-up, the open group experienced no improvement in strength from pre-operative levels and patient-ranked pain and shoulder function scores for the open group deteriorated from 2-year follow-up. The arthroscopic knotless repair group had greater external rotation strength at 5 years compared to both other groups, and was the only repair group to improve in rotator cuff functional index.

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