Journal of Orthopaedic Surgery and Research

RESEARCH Open Access

Effect of abduction brace wearing angle on clinical outcomes after arthroscopic repair of large repairable rotator cuff: a retrospective study

Jun Chen[1], Juexiang Lou[1], Weikai Wang[1], Guohong Xu[1] and Chao Lou[1*]

Abstract

Background Rotator cuff tears affect approximately 20% of the population and are usually repaired arthroscopically. The clinical outcomes of these repairs are influenced by multiple factors, including patient characteristics, surgical technique, and postoperative management. Postoperative shoulder posture, particularly the degree of abduction, plays an important role in repair site tension and tendon-bone healing. This study aimed to evaluate the clinical outcomes and repair integrity of patients undergoing arthroscopic repair of large rotator cuff tears using a 30° and 45° abduction brace.

Methods A total of 82 patients with symptomatic full-thickness rotator cuff tears were included in this study. The control group included 40 patients using a 30° brace, and the study group included 42 patients using a 45° abduction brace. Visual analogue scales (VAS) and humerohumeral range of motion were obtained before surgery and at 1 month (M1), 3 months (M3), and 6 months (M6) after surgery. Shoulder function scores (including Constant-Murley (CMS), University of California, Los Angeles (UCLA), and American Shoulder and Elbow Surgeons (ASES) scores) and retear rates were assessed at final follow-up (24 months).

Results Early passive ROM (flexion at 1 month, abduction at 1 and 3 months, external rotation at 1 and 3 months) was significantly better in the study group (45° abduction brace, $P < 0.05$). At 24 months, there were no significant differences in shoulder range of motion, function scores, and retear rates between the two groups ($P > 0.05$). Of note, in subgroup analysis, the retear rate was lower with a 45° brace than with a 30° brace under moderate to severe repair tension (16.67% vs. 44.44%, $P < 0.05$).

Conclusions These results suggest that immobilization with a 45° brace rather than a 30° abduction brace after arthroscopic repair of large rotator cuff tears results in better passive range of motion during early follow-up, particularly with lower retear rates at moderate to severe repair strains.

Keywords Brace, Rotator cuff, Arthroscopy, Shoulder, 45/30 degrees

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Introduction

Rotator cuff tears are a common shoulder pathology that affect approximately 20% of the population [1]. Therefore, arthroscopic rotator cuff repairs (ARCRs) are often performed [2, 3]. The latest progress in the management of rotator cuff tears has been emphasized, and several factors can affect the clinical and structural outcomes of ARCR, including patient specificity, technical and postoperative factors [4, 5]. Tendon healing, which is the primary concern of surgeons, is strongly correlated with the prognosis [6, 7].

Shoulder posture is essential for passive forces during rotator cuff repair surgery [8]. Rotator cuff repair tension is directly correlated with surgical outcomes, with an increased repair tension being associated with inferior shoulder function [9]. Placing the involved shoulder in an abduction brace postoperatively would reduce tension [8] and improve blood flow [10] at the tendon-to-bone repair site. However, the question remains whether it could improve the clinical tendon repair integrity and outcomes [10–16].

Postoperatively, various abduction angles can cause varying tension reduction at the repair site [17]. Furthermore, different intraoperative tear sizes, retraction, and fatty infiltration can impair tension at the repair site. Notably, tension at the repair site is not high in most conditions when tear sizes are small or medium, and subsequently, the retear rate is low [18]. Therefore, the protective benefit of an abduction brace for small-medium tears is negligible. However, for large cuff tears, tension at the repair site and the retear rate is high [19], hence, the protective benefit of bracing may be more critical. Considering the undetermined benefits of braces for different tear sizes postoperatively, and previous studies finding conflicting clinical conclusions [8, 9, 11–13], a larger abduction degree should be recommended [8, 20]. No studies have focused on the effects of different abduction braces on arthroscopically repaired large cuff tears.

Therefore, this study aimed to investigate postoperative clinical outcomes and repair integrity after arthroscopic repair of large rotator cuff tears by comparing patients immobilized with a 30° abduction brace with those immobilized with a 45° abduction brace. We hypothesized that immobilization using a larger abduction brace would result in better clinical outcomes for patients with large cuff tears.

Materials and methods

Ethics statements

The Ethics Committee of Dongyang people's hospital approved this retrospective study (approval number: 2019-YX-032), and the study experiments were conducted in accordance with the principles of the Declaration of Helsinki. Additionally, informed consent was obtained from all patients included in the study.

Patient selection

This study retrospectively reviewed patients who underwent ARCR between December 2017 and December 2019 by two surgeons at an academic hospital. The inclusion criteria were as follows: full-thickness supraspinatus or supraspinatus/infraspinatus tears diagnosed preoperatively using magnetic resonance imaging (MRI); minimum 2 years follow-up; large tears between 3 and 5 cm according to the DeOrio and Cofield classification [21]; body mass index (BMI) ≥ 18.5 kg/m^2 and ≤ 30 kg/m^2; age between 40 and 75 years; and height 150–180 cm. The exclusion criteria were as follows: partial repair or irreparable tear; refusal to undergo a structural integrity assessment by ultrasonography at a minimum of 2 years postoperatively; non-compliance with use of an abduction brace; history of previous shoulder surgery; subscapularis repair; and additional trauma or other shoulder diseases unrelated to the index surgery postoperatively.

Preoperative assessment

All patients' baseline characteristics (including comorbidities, onset, duration of symptoms, dominance, and smoking status) were recorded. All patients underwent preoperative X-ray, computed tomography (CT), and shoulder MRI examinations [22, 23]. The measurements of the rotator cuff tears were based on the maximum distance between the anterior and posterior edges of the tear in the oblique sagittal view using MRI [24]. The retraction distance was based on the maximum distance between the medial and lateral edges of the tear in the oblique coronal view using MRI [25]. The degrees of supraspinatus and infraspinatus fatty infiltration were evaluated in the oblique sagittal view of the shoulder using CT according to the Goutallier system [26].

The shoulder function scores, including the Constant–Murley score (CMS), University of California Los Angeles (UCLA) score [27], American Shoulder and Elbow Surgeons (ASES) score [28], visual analog scale (VAS) score (range, 0–10), and range of motion (ROM) by goniometers were evaluated.

Surgical procedures

Two senior surgeons at our hospital performed all surgeries with the patient under general anesthesia in the lateral decubitus position. An arthroscope was inserted into the posterior portal. Routine arthroscopic surgical procedures were performed, and the entire glenohumeral and subacromial spaces were examined. Additionally, tenotomy or tenodesis was performed during surgery to treat the biceps tendon pathology for patients younger than 60 years, highly active, and those who performed manual labor. The tendon was routinely fixed in the groove using suture anchors. After treating the glenohumeral joint lesions, arthroscopy of the subacromial space was performed to establish an anterolateral approach for acromioplasty and debridement to evaluate the tear size, retraction, and repair tension of the rotator cuff tear. Based on a previous study, the amount of tension required for footprint repair was subjective, scored by the surgeon, and classified as follows: 0, mild tension (including no and minimal tension); 1, moderate tension; and 2, severe tension [12]. The footprint area was decorticated to prepare the bone bed without medialization. Subsequently, an anchor (Johnson and Johnson or Livatec Tech) was implanted at a suitable angle. The double-row repair technique was used for all patients included in the study [24]. When necessary, margin convergence was performed using a side-to-side suture before footprint repair.

Postoperative treatment strategy and assessment

Following surgery, a brace with 30° or 45° of abduction and neutral rotation was applied. Patients hospitalized from December 2017 to November 2018 received a 30° abduction brace (control group), whereas those hospitalized from December 2018 to December 2019 received a 45° abduction brace (study group).

At different time points (1, 3, 6, and 24 months), the postoperative pain levels were evaluated by VAS. Nonsteroidal anti-inflammatory drugs were the dominant analgesics routinely used within 2 weeks postoperatively; opioid medication was also administered for intolerable pain.

All patients were instructed to wear a brace for 4 weeks postoperatively. When immobilization was phased out, the patients were questioned about their satisfaction with the brace. The level of satisfaction with the comfort brace was classified into three levels based on the patients' subjective feelings: 0, very comfortable, implying that patients felt more comfortable wearing an abduction brace than not wearing it; 1, equal, meaning that patients felt no difference when wearing or not wearing a brace; 2, worse, indicating that patients felt worse when wearing the abduction brace. According to rehabilitation guidelines, a standardized rehabilitation program was directed by the same senior physical therapist [29]. Postoperatively, local wrist and elbow joint activities were initiated immediately. Passive shoulder joint activities were started 2 weeks postoperatively with restricted passive ROM up to 60° abduction, 60° forward flexion, and 15° external rotation in the scapular plane. Assisted active exercises were initiated 6 weeks later. Resistance exercises were performed 3 months thereafter. The individual rehabilitation process was determined through consensus between the surgeon, physical therapist, and patient, and online and offline consultants were available to follow-up with patients and monitor the rehabilitation progress.

During follow-up, the patient visited the outpatient department for assessment of the VAS score for pain, and passive glenohumeral ROM including forward flexion, abduction, and external rotation. Additionally, at 24 months postoperatively, shoulder function scores (including CMS, UCLA, and ASES scores) were assessed by two surgeons, and ultrasonography was performed by an experienced orthopedist. For ultrasound diagnosis criteria [30, 31], complete healing was considered a watertight cuff without tendon defects. Retears were defined as distinct echogenic defects in both the transverse and longitudinal planes.

Statistical analysis

Statistical analyses were performed using SPSS (version 22.0; IBM Corp.). Statistical significance was set at $P < 0.05$. Normally distributed data and non-normally distributed variables are expressed as the mean ± standard deviation and medians (interquartile ranges), respectively. The equal distribution of baseline characteristics was evaluated using Student's t-test and chi-square test for continuous and categorical variables, respectively. A repeated-measures analysis of variance (ANOVA) was performed for normally distributed preoperative and postoperative data. A post hoc analysis was calculated using the Power Analysis and Sample Size Software (PASS 2019; USA).

Results

A total of 109 patients with full-thickness rotator cuff tears from December 2017 to December 2019 met the inclusion criteria. However, 12 and 15 patients were excluded from the control and study groups, respectively. Finally, 82 patients (38 men and 44 women) with the following characteristics were enrolled in the study (Fig. 1): age, 63.78 ± 7.05 years; BMI, 23.81 ± 2.91 kg/m^2; height, 160.51 ± 6.79 cm; affected dominant side, 64 cases; traumatic tear, 37 cases; non-traumatic tear, 45 cases; duration of symptoms, 5.48 ± 7.78 months; diabetes mellitus, 6 cases; hypertension, 21 cases; and current smoking, 21 cases. All patients successfully underwent surgery without serious complications or requiring revision surgery and completed the minimum two-year follow-up.

The control and study groups comprised 40 patients with a 30° abduction brace and 42 patients with a 45° abduction brace, respectively (Table 1). Notably, no statistical differences in sex, BMI, height, affected dominant side, traumatic tear, duration of symptoms, presence of diabetes mellitus, smoking, hypertension, follow-up length, tear size, extent of retraction, fatty infiltration of the supraspinatus and infraspinatus, biceps procedures,

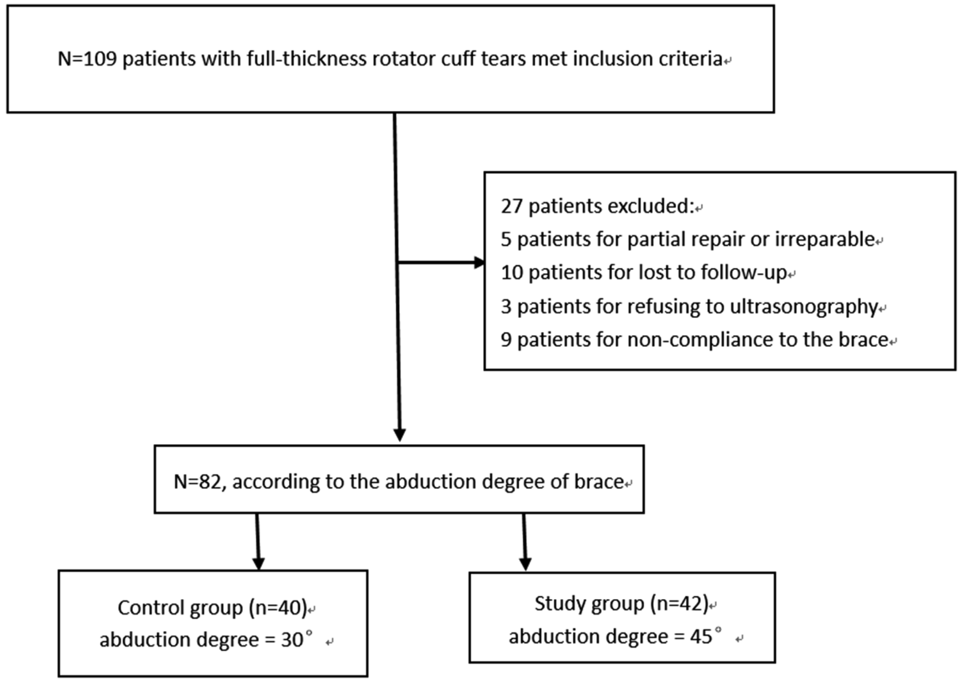

Fig. 1 Study flowchart. Flowchart describing the patient selection process of the study

and repair tension were observed between the groups (all $P > 0.05$).

In both groups, the ANOVA test pairwise comparison showed that there were highly significant reduction ($P < 0.05$) in pain level indicated by VAS scores over time during the follow-up. The VAS scores at M6 after surgery in the control group (0.78 ± 0.66) and the study group (0.79 ± 0.47) were lower than those in the control group (6.73 ± 1.11) and the study group (7.05 ± 1.06) before surgery. However, the independent sample t-test showed that there was no statistically significant difference in the VAS scores between the two groups from preoperative to M6 (Fig. 2).

It is worth noting that, as shown in Figs. 3, 4 and 5, the passive flexion, glenohumeral joint abduction, and external rotation range of motion of the two groups of patients from M1 to M3 and M3 to M6 after surgery were significantly improved compared with those before surgery (all P values < 0.05). The independent sample t test showed that there were statistical differences in M1 flexion, M1 and M3 abduction, and M1 and M3 external rotation between the two groups (all P values < 0.05), while there were no statistically significant differences in shoulder joint range of motion between the two groups at other time points (all P values < 0.05) (Table 2).

When the brace was phased out, patients were cross-examined regarding their comfort. Although the comfort rate of the control group was higher than that of the study group (82.5% vs. 80.95%, respectively), the difference was not significant (Table 1). Three months after surgery, three and one patients in the control and study groups, respectively, were diagnosed with adhesive shoulder caused by pain and limited ROM. Two of these patients in the control group received corticosteroids. At final follow-up, all four patients regained substantial shoulder function without other invasive interventions.

Compared with the preoperative stage, shoulder function of both groups at the final follow-up evaluation was significantly improved ($P < 0.05$). The CMS increased from 47.13 ± 4.50 and 47.07 ± 2.80 in the control and study groups to 92.30 ± 5.42 and 93.07 ± 3.61, respectively. Similarly, the ASES score increased from 49.23 ± 3.83 and 47.94 ± 4.45 in the control and study groups to 91.73 ± 4.37 and 92.38 ± 3.06, respectively. Furthermore, the UCLA score increased from 15.15 ± 2.90 and 15.24 ± 2.25 in the control and study groups to 33.40 ± 1.35 and 33.52 ± 1.27, respectively. No significant differences in the CMS, ASES, and UCLA scores at the final follow-up evaluation were observed between groups ($P > 0.05$) (Table 3).

Ultrasonography at a minimum of 24 months postoperatively revealed nine and eight cases of retears in the control and study groups, respectively. There were no significant differences in the retear rate between the two groups (22.5% vs. 19.05%, $P > 0.05$). Furthermore, during subgroup analysis, under moderate to severe repair tension, the study group had a lower retear rate than the control group (16.67% vs. 44.44%, $P < 0.05$) (Table 3).

Table 1 Patient Demographics, surgical findings and adherence to therapy(*N* = 82). The mean and standard deviation of the continuous variables and the frequencies of the categorical data are presented. BMI, body mass index; VAS, visual analog score; GH, glenohumeral

Variable	Control group (*N* = 40)	Study group (*N* = 42)	*P* Value
Age (year)	63.50 ± 6.69	64.05 ± 7.45	0.727
Sex (male: female) (n)	15:25	23:19	0.117
BMI (kg/m^2)	23.85 ± 3.05	23.76 ± 2.80	0.892
Height (cm)	159.48 ± 6.70	161.50 ± 6.80	0.178
Traumatic (yes: no) (n)	16:24	21:21	0.363
Location (left: right) (n)	5:35	8:34	0.417
Symptoms duration (months)	6.87 ± 8.93	4.15 ± 6.31	0.113
Diabetes mellitus, n (%)	3(7.50%)	3(7.14%)	0.951
Hypertension, n (%)	8(20%)	13(30.95%)	0.256
Smoking, n (%)	9(22.5%)	12(28.57%)	0.529
Preoperative assessment			
Pain, VAS score	6.73 ± 1.11	7.05 ± 1.06	0.181
GH forward flexion	120.30 ± 13.22	120.95 ± 13.03	0.823
GH abduction	84.20 ± 13.10	83.55 ± 11.03	0.808
GH external rotation	32.15 ± 10.14	32.98 ± 9.76	0.708
Tear size (cm)	3.69 ± 0.41	3.60 ± 0.39	0.315
Extent of retraction (cm)	2.63 ± 0.53	2.72 ± 0.71	0.555
Fatty infiltration (0:1:2:3:4)			
supraspinatus	8:21:8:3:0	14:17:8:3:0	0.570
infraspinatus	12:18:6:4:0	14:19:7:2:0	0.831
Repair tension (0:1:2)	22:16:2	18:17:7	0.206
Biceps procedures			0.796
Tenodesis	12	14	
Tenotomy	21	19	
Comfort of brace			0.972
0 = better	33	34	
1 = equal	5	6	
2 = worse	2	2	

Note: Of the continuous variables the mean and standard deviation are presented. Of the categorical data, the frequencies are presented. BMI = body mass index, VAS = visual analogue score

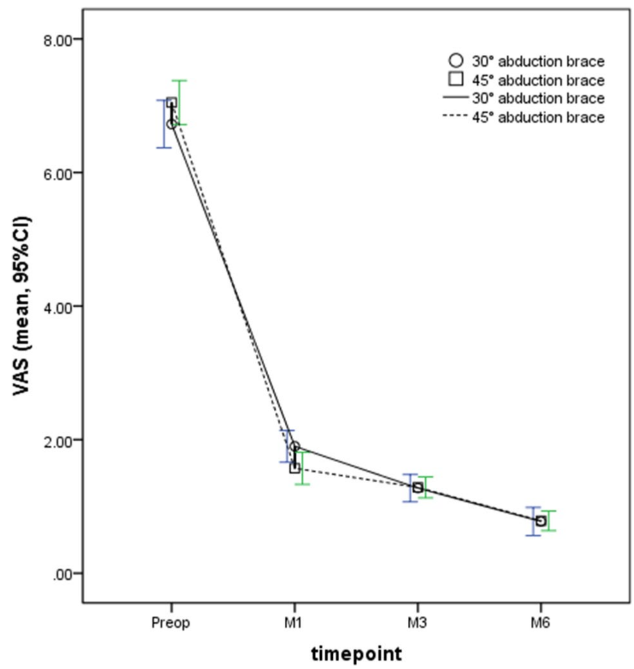

Fig. 2 The pain scores of the 2 groups during follow-up. No significant differences were found. (VAS = visual analog scale, M1 = 1 month after surgery, M3 = 3 months after surgery, M6 = 6 months after surgery)

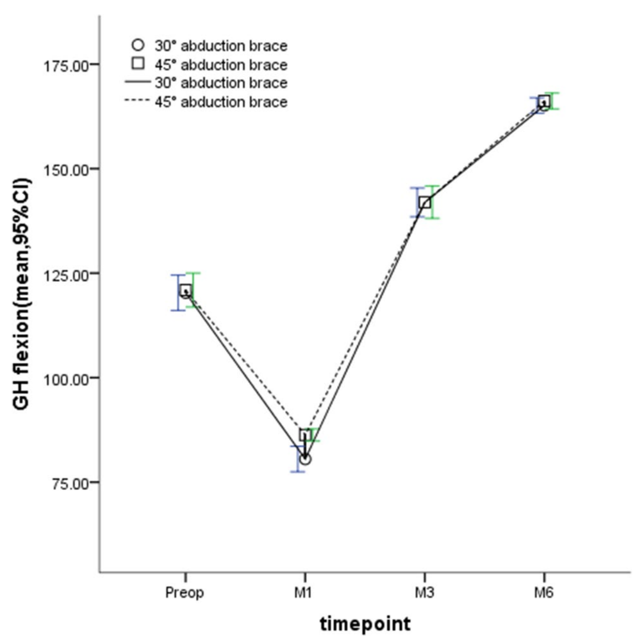

Fig. 3 The glenohumeral forward flexion of the 2 groups. Patients with 45° abduction brace was significant greater at M1. (GH = glenohumeral)

Discussion

In this study, a significantly higher passive shoulder ROM was obtained with the use of the 45° abduction brace at 1 and 3 months, but not at 6 and 24 months. During subgroup analysis, under moderate-to-severe repair tension, the 45° brace result in lower retear rate than 30°. However, pain and shoulder function were not significantly different at the final follow-up evaluation. Therefore, the findings of this study suggest that the patients immobilized with a 45° abduction brace experienced better passive ROM during short term follow-up (1 and 3 months), and the healing of large cuff tears under moderate-to-severe repair tension after arthroscopic surgery can be improved with a larger abduction angle brace.

Many operative repair techniques have been developed to help reduce the retear rate after the repair of large rotator cuff tears [32]. Nevertheless, the retear rate of large rotator cuff tears remains high [33], as was found in our study (approximately 20%). Many factors, including age [5], tear size [19], diabetes mellitus [34], and repair tension [9] have been shown to correlate with tendon healing after cuff repair. In this study, there were no significant differences in retear rate between the two groups. But in

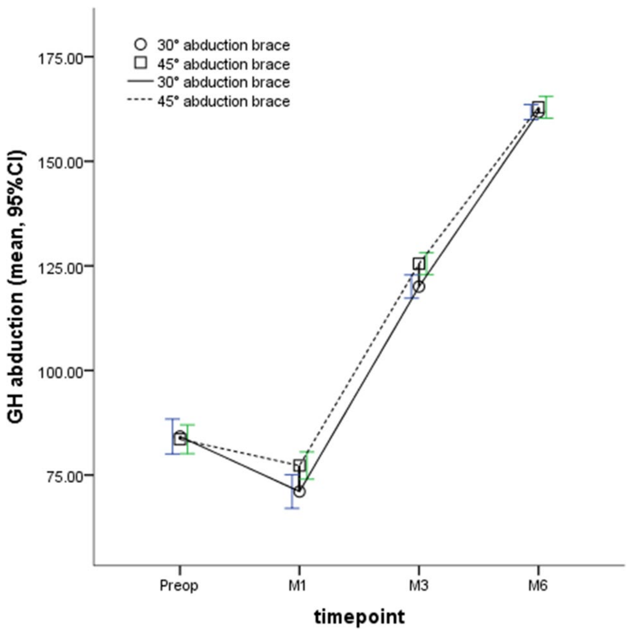

Fig. 4 The glenohumeral abduction of the 2 groups. Patients with 45° abduction brace was significant greater at M1 and M3. (GH = glenohumeral)

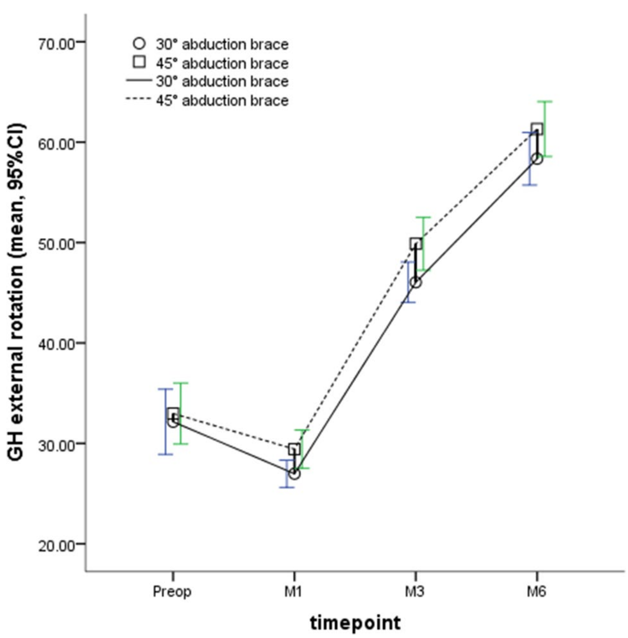

Fig. 5 The glenohumeral external rotation (arm at side) of the 2 groups. Patients with 45° abduction brace was significant greater at M1 and M3. (GH = glenohumeral)

Table 2 Pain and ROM comparisons between two groups (*N* = 82). The mean and standard deviation of the continuous variables are presented and the frequencies of the categorical data are presented

Variable	Control group (*N* = 40)	Study group (*N* = 42)	*P* Value
Preoperative			
VAS	6.73 ± 1.11	7.05 ± 1.06	0.181
flexion	120.30 ± 13.22	120.95 ± 13.03	0.823
abduction	84.20 ± 13.10	83.55 ± 11.03	0.808
rotation	32.15 ± 10.14	32.98 ± 9.76	0.708
1month after surgery			
VAS	1.90 ± 0.74	1.57 ± 0.77	0.053
flexion	80.53 ± 9.53	86.29 ± 4.68	0.001
abduction	71.05 ± 12.56	77.26 ± 10.42	0.017
rotation	26.98 ± 4.25	29.43 ± 6.09	0.038
3 months after surgery			
VAS	1.28 ± 0.64	1.29 ± 0.51	0.933
flexion	141.93 ± 10.78	141.98 ± 12.33	0.984
abduction	120.05 ± 8.75	125.50 ± 8.45	0.005
rotation	46.05 ± 6.26	49.88 ± 8.45	0.023
6 months after surgery			
VAS	0.78 ± 0.66	0.79 ± 0.47	0.933
flexion	165.13 ± 5.78	166.19 ± 6.03	0.417
abduction	161.75 ± 5.63	162.88 ± 8.32	0.475
rotation	58.35 ± 8.20	61.31 ± 8.77	0.119

Note: VAS, visual analog scale

Table 3 Clinical outcomes comparisons between two groups (*N* = 82). The mean and standard deviation of the continuous variables are presented. The frequencies of the categorical data are presented

Variable	Control group (*N* = 40)	Study group (*N* = 42)	*P* Value
Preoperative			
CMS	47.13 ± 4.50	47.07 ± 2.80	0.949
ASES	49.23 ± 3.83	47.94 ± 4.45	0.164
UCLA	15.15 ± 2.90	15.24 ± 2.25	0.878
Final follow-up after surgery			
CMS	92.30 ± 5.42	93.07 ± 3.61	0.448
ASES	91.73 ± 4.37	92.38 ± 3.06	0.432
UCLA	33.40 ± 1.35	33.52 ± 1.27	0.671
Retear, n (%)	9(22.5%)	8(19.05%)	0.700
MSRT Subgroup concrete	8 (44.44%)	4 (16.67%)	0.049

Note: CMS = the Constant–Murley score, UCLA = University of California Los Angeles score, and ASES = American Shoulder and Elbow Surgeons scores, MSRT subgroup, moderate-to-severe repair tension subgroup

subgroup analysis, under moderate-to-severe repair tension, the 45° brace resulted in a lower retear rate than the 30° brace. Therefore, abduction degree may produce better benefits with relative high tension conditions. However, the exact cutoff value of repair tension or abduction degree to determine healing or retear is unclear.

Different shoulder positions can result in various clinical outcomes. Conti et al. [11] compared the clinical effects of two different braces after rotator cuff repair (15° external rotation brace and internal rotation sling) and found that during a short time after arthroscopic surgery, patients immobilized with a 15° external rotation brace reported less pain and better passive ROM; however, at the 6-month follow-up evaluation, no significant functional difference was observed. Furthermore, a study by Jackson et al. [35] found that the immobilization prescription should be based on the conditions of the repaired tear. Appropriate immobilization will reduce stress at the repair site, thus reducing retear rates. Haering et al. [36] found that larger tear size and multiple tendon tears decreased safe ROM and glenohumeral flexion between 38° and 65°, and holding the arm in external rotation caused less stress during movement for most types and sizes of injuries.

Appropriate arm positioning during the early healing phases is vital to reduce stress on the repaired cuff. Moreover, using a brace with an abductor pillow with an average of 30° in the scapular plane is reported to reduce tensile force on the repaired superior cuff [37]. Schenk et al. [38] demonstrated that the most comfortable brace position involves low angles of abduction (30° to 50°) in the scapular plane, which are associated with the highest load transfer to the brace. Furthermore, this study showed that a greater postoperative abduction angle resulted in regaining joint ROM earlier; however, it did not influence long term function and healing. Therefore, further research should be conducted to determine the optimal shoulder position (abduction and rotation) for each patient.

The role of brace immobilization in rotator cuff tendon healing after rotator cuff repair remains controversial. Galatz et al. [39] found that complete load removal is harmful to rotator cuff healing, particularly when combined with immobilization. However, a simulation analysis [8] concluded that more abducted postures during the repair of rotator cuff tears with larger gaps might lead to increased failure postoperatively. Therefore, a controlled balance should be reached between loads that are too low (leading to a catabolic state) and too high (leading to microdamage) [40]. Suitable loading can improve healing in most conditions.

Similar to our study, the prospective comparative studies by Ghandour et al. [12] and Hollman et al. [13] found no significant differences in patient oriented outcome measures (including shoulder function scores and joint ROM) or postoperative pain after rotator cuff repair with an abduction brace and that with an anti-rotation sling. Furthermore, Hollman et al. [13] compared the retear rate 3 months postoperatively using ultrasonography and found no significant differences. In contrast to our study, patients included in the aforementioned studies had cuff tears of different sizes (ranging from small to massive), which led to inconsistent rotator cuff properties and the follow-up was relatively short. Jerosch et al. [20] concluded that neutral rotation and at least 30° of abduction are required to obtain tensionless repair, and that 60° of abduction is recommended for tear sizes larger than 2 cm. Although the total retear rate of the two groups were not different in our study, under moderate-to-severe repair tension, the retear rate of the study group was lower. Thus, it is possible that 45° of abduction was insufficient for large cuff repair under mild tension to improve tendon healing. Therefore, comparisons of groups with larger abduction angle differences and serial repaired tendon evaluations are required to determine the exact impact of abduction braces on large rotator cuff tears.

This study had certain limitations. First, it was a retrospective study, the sample size was small, and the level of evidence was low. However, according to the post hoc analysis using effect size of 0.8, alpha of 0.05, the power (1-β) achieved above 0.8. Second, the exact abduction degree was unclear because of the heterogeneity of body height; therefore, the height was restricted to a specific range (150–180 cm based on the inclusion criteria) to reduce this bias. Third, the brace wearing compliance was assessed subjectively. According to a previous study [41], the wearing time was significantly greater when assessed subjectively, rather than objectively. Therefore, actual compliance might have influenced tendon healing.

Conclusion

Patients immobilized with a 45° abduction brace, rather than a 30° brace, resulted in better passive ROM during early stage follow-up (1 and 3 months) and a lower retear rate under moderate-to-severe repair tension after arthroscopic surgery to repair a large cuff tear.

Acknowledgements
This work was funded by Key Projects of Jinhua Science and Technology Bureau (2024-3-107).

Author contributions
J.C. and C.L. designed the study. J.C. wrote the main manuscript. J.X.L. and W.K.W. contributed to the data analysis. All authors reviewed the manuscript.

Data availability
No datasets were generated or analysed during the current study.

Declarations

Competing interests
The authors declare no competing interests.

Received: 22 February 2025 / Accepted: 3 April 2025
Published online: 10 April 2025

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