

# Association of Preoperative Vitamin D Deficiency With Retear Rate and Early Pain After Arthroscopic Rotator Cuff Repair

## A Retrospective Cohort Study

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**Background:** Although the function of vitamin D in bone metabolism has been well studied, the question remains whether vitamin D deficiency impairs tendon healing after rotator cuff repair.

**Purpose:** To investigate the correlation between preoperative vitamin D deficiency and the re-tear rate and pain after arthroscopic rotator cuff repair.

**Study Design:** Cohort study; Level of evidence, 3.

**Methods:** Patients with full-thickness rotator cuff tears who underwent arthroscopic rotator cuff repair between January 2018 and August 2019 were enrolled. Included patients were divided into a control group (vitamin D level  $\geq 20$   $\mu\text{g/L}$ ) and a deficiency group (vitamin D level  $< 20$   $\mu\text{g/L}$ ). We investigated the association between preoperative vitamin D level and patient characteristics, MRI findings, pain and function scores (visual analog scale [VAS] for pain; Constant-Murley; University of California, Los Angeles; and American Shoulder and Elbow Surgeons scores), and healing status using the Pearson or Spearman correlation coefficient. The clinical characteristics were compared between the groups using the chi-square test or Fisher exact test.

**Results:** Included were 89 patients (control group, 44 patients; deficiency group, 45 patients). The mean vitamin D levels were  $25.07 \pm 5.38$  and  $14.61 \pm 3.43$   $\mu\text{g/L}$  in the control and deficiency groups, respectively ( $P < .001$ ); otherwise, there were no significant differences between the groups in the variables under study. Vitamin D levels were not related to age, symptom duration, tear size, extent of retraction, VAS pain score preoperatively and at 6 and 24 months postoperatively, or any function scores. Supraspinatus fatty infiltration and VAS scores at 1 and 3 months postoperatively were significantly associated with vitamin D level ( $r = -0.360$ ,  $-0.362$ , and  $-0.316$ , respectively;  $P < .05$  for all). VAS scores were significantly lower in the control group than in the deficiency group at postoperative 1 month ( $1.09 \pm 0.56$  vs  $1.47 \pm 0.66$ , respectively) and 3 months ( $1.14 \pm 0.77$  vs  $1.44 \pm 0.66$ ) ( $P < .05$  for both). The re-tear rate was significantly lower in the control group than in the deficiency group (9.09% vs 26.67%, respectively;  $P < .05$ ).

**Conclusion:** Our study revealed that preoperative vitamin D deficiency was associated with a higher re-tear rate and early pain (1 and 3 months) after arthroscopic rotator cuff repair.

**Keywords:** vitamin D; rotator cuff; shoulder; arthroscopy; outcome

Rotator cuff tear is a common injury of the shoulder joint. According to an epidemiological survey of different age groups, the prevalence of rotator cuff injury in people older than 60 years is  $>25\%$ .<sup>38</sup> Shoulder pain and dysfunction are the main clinical manifestations that seriously affect patients' quality of life. At present, arthroscopic rotator cuff repair is the most effective strategy for treating full-thickness rotator cuff tears. Retear and pain after operation

are the main concerns of patients. Many factors affect the outcomes after rotator cuff repair, including patient- and surgery-related factors, such as age, tear size, degree of fatty infiltration, smoking, presence of diabetes, osteoporosis, vitamin D levels, and suture technology.<sup>1,23,29</sup>

Vitamin D deficiency is prevalent among patients who have undergone arthroscopic rotator cuff repair.<sup>17,21,25,34</sup> Vitamin D can regulate the metabolism of calcium and phosphorus, and it also participates in the regulation of cell proliferation and differentiation of the immune system. In addition to its role in bone growth and metabolism, the role of vitamin D in tendon healing after surgery has received

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increasing attention.<sup>9,19</sup> Experiments in mice have confirmed that vitamin D deficiency impairs early tendon healing after rotator cuff surgery,<sup>2</sup> and vitamin D supplementation can enhance postoperative tendon healing.<sup>19</sup>

Despite the high prevalence of serum vitamin D deficiency among patients with rotator cuff tears, few studies have studied the vitamin D level in relation to rotator cuff healing and pain after repair. Therefore, this study aimed to evaluate the correlation between preoperative vitamin D deficiency and the retear rate and pain after arthroscopic rotator cuff repair. We hypothesized that preoperative vitamin D deficiency would be associated with a higher retear rate and early pain after arthroscopic rotator cuff repair.

## METHODS

### Patient Selection

The protocol for this retrospective cohort study was approved by the hospital ethics committee, and informed consent was obtained from the study patients. Patients who underwent arthroscopic repair for a full-thickness rotator cuff tear between January 2018 and August 2019 were screened for this study. The inclusion criteria were as follows: (1) patients with full-thickness supraspinatus or supraspinatus/infraspinatus tears, in whom small- to large-sized tears (tear size <5 cm) were preoperatively diagnosed by magnetic resonance imaging (MRI); (2) patients in whom the preoperative serum vitamin D level (25-hydroxyvitamin D,  $\mu\text{g/L}$ ) was tested; (3) patients aged  $\geq 40$  years and  $\leq 75$  years; and (4) patients with a body mass index (BMI)  $\geq 18.5$  and  $\leq 30$   $\text{kg/m}^2$ . The exclusion criteria were as follows: (1) patients who underwent single-row repair technique; (2) patients who had additional trauma or other shoulder diseases not related to the index surgery postoperatively; (3) patients who did not undergo MRI assessment of structural integrity at a minimum of 2 years postoperatively; and (4) patients who had received vitamin D supplementation postoperatively.

All patients had undergone serum vitamin D testing, computed tomography (CT) scan, and MRI scan before the operation. Measurement of the size of the rotator cuff tear was based on the maximum distance between the anterior and posterior edges of the tear in the oblique sagittal view of MRI scan<sup>6</sup>; the retraction distance was based on the maximum distance between the medial and lateral edges of the tear in the oblique coronal view of MRI scan<sup>8</sup>; and the degree of supraspinatus fatty infiltration was evaluated in the oblique sagittal view of the shoulder CT scan according

to the Goutallier system.<sup>12</sup> According to previous criteria,<sup>18</sup> a serum vitamin D level  $<20$   $\mu\text{g/L}$  was diagnosed as vitamin D deficiency. Included patients were divided into 2 groups: the deficiency group (vitamin D level  $<20$   $\mu\text{g/L}$ ) and the control group (vitamin D level  $\geq 20$   $\mu\text{g/L}$ ).

### Surgical Procedures

All operations were completed by the same senior surgeon (G.X.) at our hospital with the patient under general anesthesia in the lateral decubitus position. Routine arthroscopic surgical procedures were performed, and the entire glenohumeral joint was explored. During operation, tenotomy or tenodesis was used for biceps lesions, and debridement was used for labral injuries without shoulder instability. After the glenohumeral joint lesions were treated, arthroscopy was transferred to the subacromial space to establish an anterolateral approach to perform acromion plasty and debridement to evaluate the size and repair tension of the rotator cuff tear. The footprint area was decorticated to prepare the bone bed. Then, an anchor (Johnson & Johnson or Linvatec Tech) was implanted at a suitable angle. The double-row repair technique was used in all patients included in the study.

### Postoperative Pain Management and Rehabilitation

Nonsteroidal anti-inflammatory drugs (NSAIDs) as basic analgesics were used within 2 weeks after surgery, and opioid medication was added for intolerated pain. After that, NSAIDs and opioid medication were rarely prescribed.

According to rehabilitation guidelines,<sup>37</sup> the postoperative rehabilitation program was performed in stages. A progressive rehabilitation program was adopted for patients with small- and medium-sized tears, with local wrist and elbow joint activities in the first 3 weeks postoperatively, passive shoulder exercises at 3 to 6 weeks, and assisted shoulder activities from 6 weeks to 3 months. After 3 months, the patient could transition from partial resistance activities to normal sports activities. For large tears, we chose a delayed rehabilitation program. Passive shoulder joint activities were started 6 weeks postoperatively, active-assisted exercises were started 8 weeks later, and resistance exercises were performed 3 months later. However, the individual rehabilitation process was determined by the consensus of the surgeon, rehabilitation physician, and patient.

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Ethical approval for this study was obtained from Dongyang People's Hospital (ref No. 2019-YX-057).

### Evaluation of Clinical Outcomes

Each patient in the study was assessed preoperatively and at minimum 2-year follow-up. The following evaluations were used: visual analog scale (VAS) for pain score; University of California, Los Angeles (UCLA) score;<sup>10</sup> American Shoulder and Elbow Surgeons (ASES) score;<sup>33</sup> and Constant-Murley score.<sup>7</sup> In addition, the VAS score was assessed at 1 month, 3 months, and 6 months postoperatively.

The postoperative MRI scans were interpreted by a senior radiologist using a picture archiving and communications system workstation. The radiologist was blinded to each patient's serum vitamin D level. Postoperative integrity of the rotator cuff structure was classified according to the Sugaya<sup>36</sup> system: type 1, sufficient thickness compared with a normal cuff with homogeneously low intensity on MRI scan; type 2, sufficient thickness compared with a normal cuff associated with a partial high-intensity area on MRI scan; type 3, insufficient thickness with less than half the thickness when compared with a normal cuff, but without discontinuity; type 4, the presence of a minor discontinuity on only 1 or 2 slices on oblique coronal and sagittal images; and type 5, a major discontinuity observed on >2

slices on both oblique coronal and sagittal images. Tears classified as types 4 and 5 were defined as retears.

Any complications or clinical failures were recorded. Joint infection was diagnosed when the patient reported a swollen joint, there was pus from the incision, and a microbial culture was positive. Anchor withdrawal was assessed according to radiological images. Revision surgery for any reason (eg, infection, stiffness, retear) was recorded.

### Statistical Analysis

Normally distributed data were reported as mean ± standard deviation, and non-normally distributed variables were reported as median with interquartile range. A non-parametric test was used to analyze nonnormally distributed data. Count data were expressed as percentages, and they were compared between the groups using the chi-square test or Fisher exact test. Pearson or Spearman correlation coefficients were calculated for correlations between the vitamin D level and other variables. SPSS Version 22.0 software (IBM) was used to conduct the statistical analyses. A *P* value <.05 was regarded as statistically significant.

### RESULTS

Of an initial 135 patients, 89 patients were included in the study (Figure 1). There were 36 men and 53 women; their mean age was 61.20 ± 7.43 years, mean BMI was 23.55 ± 2.74 kg/m<sup>2</sup>, and mean symptom duration was 5.73 ± 7.70 months (Table 1). The mean vitamin D level was 19.78 ± 6.91 µg/L, and 45 patients were vitamin D deficient, accounting for about 50.56% of the study population (Table 1). All patients successfully underwent the operation and completed the follow-up. There were no serious complications in any patients.

Correlations between vitamin D level and the other variables are shown in Table 2. Results indicated that BMI, degree of supraspinatus fatty infiltration, and VAS score at 1 month and 3 months postoperatively were correlated with vitamin D level (*P* < .05 for all).

There were 45 patients in the deficiency group and 44 patients in the control group. Table 3 shows the demographic and clinical characteristics of each group. Aside

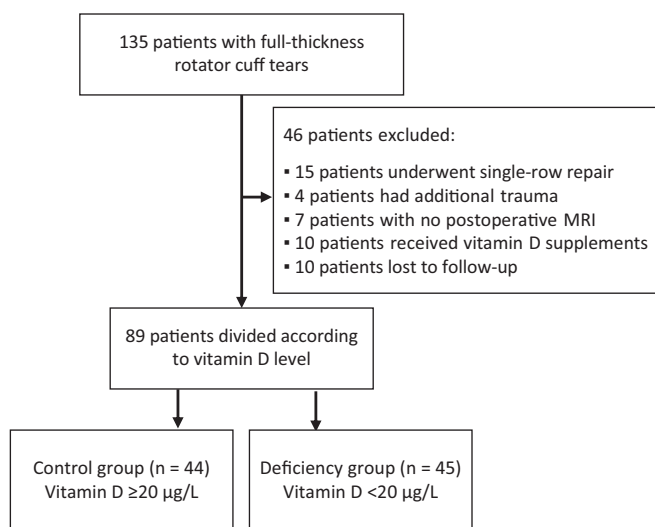


Figure 1. Study flowchart. MRI, magnetic resonance imaging.

TABLE 1  
Demographic and Clinical Characteristics of All Patients (N = 89)<sup>a</sup>

Demographic Characteristics	Value	Clinical Characteristics	Value
Age, y	61.20 ± 7.43	Tear size, cm	1.96 ± 0.86
Sex, male/female, n	36/53	Degree of fatty infiltration (Goutallier stage)	1.40 ± 0.96
Body mass index, kg/m <sup>2</sup>	23.55 ± 2.74	Extent of retraction, cm	2.00 ± 0.94
Traumatic injury, yes/no, n	49/40	Symptom duration, mo, median (IQR)	2 (1-7.5)
Location, left/right, n	25/64	Serum vitamin D level (µg/L)	19.78 ± 6.91
Diabetic, n (%)	9 (10.11)	Vitamin D deficiency, n (%)	45 (50.56)
Smoker, n (%)	19 (21.35)		

<sup>a</sup>Data are presented as mean ± SD unless otherwise indicated. IQR, interquartile range.

from vitamin D level, there were no significant differences between the groups.

The preoperative and postoperative VAS pain scores in the control and deficiency groups are shown in Table 4. Compared with preoperative scores, VAS pain scores at all time points after the operation were significantly reduced

in patients in both groups ( $P < .05$  for all). The VAS score was significantly lower in the control group than in the deficiency group at 1 month and 3 months postoperatively ( $P < .05$  for both). The mean preoperative and postoperative Constant-Murley, UCLA, and ASES scores of both groups are also shown in Table 4. We found no significant differences in the preoperative or postoperative Constant-

TABLE 2  
Correlation of the Vitamin D Level With Other Variables<sup>a</sup>

Variable	<i>r</i>	<i>P</i> Value
Age	-0.069	.523
Body mass index	-0.268	<b>.011</b>
Symptom duration	-0.050	.645
Tear size	-0.037	.728
Degree of fatty infiltration	-0.360	.556
Extent of retraction	0.063	.936
VAS pain score		
Preoperative	-0.030	.781
1 mo postoperative	-0.362	<b>&lt;.001</b>
3 mo postoperative	-0.316	<b>.003</b>
6 mo postoperative	-0.113	.292
24 mo postoperative	-0.199	.061
UCLA score		
Preoperative	0.074	.488
Postoperative	-0.120	.262
Constant-Murley score		
Preoperative	0.021	.844
Postoperative	-0.175	.101
ASES score		
Preoperative	-0.100	.350
Postoperative	-0.142	.183

<sup>a</sup>Boldface *P* values indicate statistical significance ( $P < .05$ ). ASES, American Shoulder and Elbow Surgeons; UCLA, University of California Los Angeles; VAS, visual analog scale.

TABLE 4  
Comparison of Pain and Functional Outcome Scores Between the Groups<sup>a</sup>

Variable	Control Group (n = 44)	Deficiency Group (n = 45)	<i>P</i> Value
VAS pain score			
Preoperative	7.11 ± 0.84	7.13 ± 0.87	.914
1 mo postoperative	1.09 ± 0.56	1.47 ± 0.66	<b>.005</b>
3 mo postoperative	1.14 ± 0.77	1.44 ± 0.66	<b>.045</b>
6 mo postoperative	1.14 ± 0.80	1.20 ± 0.59	.668
24 mo postoperative	0.68 ± 0.64	0.87 ± 0.55	.147
UCLA score			
Preoperative	15.30 ± 2.98	14.64 ± 2.67	.280
Postoperative	33.05 ± 1.12	33.16 ± 1.04	.632
Constant-Murley score			
Preoperative	47.43 ± 4.80	46.47 ± 4.31	.321
Postoperative	85.07 ± 3.90	85.20 ± 4.14	.877
ASES score			
Preoperative	47.58 ± 4.16	48.30 ± 4.43	.431
Postoperative	84.62 ± 5.37	85.96 ± 5.36	.244

<sup>a</sup>Data are reported as mean ± SD. Boldface *P* values indicate statistical significance ( $P < .05$ ). ASES, American Shoulder and Elbow Surgeons; UCLA, University of California–Los Angeles; VAS, visual analog scale.

TABLE 3  
Comparison of Demographic and Clinical Characteristics Between the Study Groups<sup>a</sup>

Variable	Control Group (n = 44)	Deficiency Group (n = 45)	<i>P</i> Value
Age, y	60.61 ± 7.62	61.78 ± 7.29	.463 <sup>b</sup>
Sex, male/female, n	19/25	17/28	.604 <sup>c</sup>
Body mass index, kg/m <sup>2</sup>	23.15 ± 2.76	23.95 ± 2.70	.171 <sup>b</sup>
Diabetic, n	4	5	.752 <sup>c</sup>
Smoker, n	10	9	.754 <sup>c</sup>
Traumatic injury, yes/no, n	26/18	23/22	.449 <sup>c</sup>
Location, left/right, n	13/31	12/33	.763 <sup>c</sup>
Symptom duration, mo	6.09 ± 6.96	5.37 ± 8.41	.055 <sup>d</sup>
Tear size, cm	1.91 ± 0.87	2.00 ± 0.85	.644 <sup>b</sup>
Degree of fatty infiltration (Goutallier stage)	1.20 ± 0.93	1.60 ± 0.96	.052 <sup>b</sup>
Goutallier stage >2, n	3	6	.308 <sup>c</sup>
Extent of retraction, cm	1.95 ± 0.97	2.07 ± 0.90	.549 <sup>b</sup>
No. of anchors	2.80 ± 0.98	2.56 ± 0.66	.180 <sup>b</sup>
Serum vitamin D level, µg/L	25.07 ± 5.38	14.61 ± 3.43	<b>&lt;.001<sup>b</sup></b>

<sup>a</sup>Data are reported as mean ± SD unless otherwise noted. Boldface *P* value indicates statistical significance ( $P < .05$ ).

<sup>b</sup>Independent-samples *t* test.

<sup>c</sup>Chi-square test.

<sup>d</sup>Nonparametric test.

TABLE 5

Comparison of Tear Type and Retear Rate at Final Follow-up Between the Groups

	Control Group (n = 44)	Deficiency Group (n = 45)
Sugaya type, n		
Type 1	20	7
Type 2	11	13
Type 3	9	13
Type 4 <sup>a</sup>	2	8
Type 5 <sup>a</sup>	2	4
Retear rate, %	9.09	26.67
<i>P</i>		.031 <sup>b</sup>

<sup>a</sup>Defined as retear.<sup>b</sup>Statistically significant difference ( $P < .05$ ,  $\chi^2$  test).

Murley, UCLA, or ASES scores between the groups (Table 4).

The distribution of tear types and the retear rates for each group are shown in Table 5. We noted a significant difference in the retear rate between the groups ( $P < .05$ ). In addition, although the preoperative VAS score was not correlated with type of retear, VAS scores at 1, 3, 6, and 24 months postoperatively were positively correlated with type of retear ( $P < .05$  for all) (Table 6).

## DISCUSSION

This study is the first to describe VAS scores after arthroscopic repair in relation to the serum vitamin D level. After the operation (1 and 3 months), the pain score was negatively correlated with the vitamin D level ( $r = -0.362$  and  $-0.316$ , respectively;  $P < .05$ ). At 6 and 12 months postoperatively, the VAS scores were not correlated with the vitamin D level ( $r = -0.113$  and  $-0.199$ , respectively;  $P > .05$ ). After the operation, the deficiency group, when compared with the control group, had more severe early pain ( $1.47 \pm 0.66$  vs  $1.09 \pm 0.56$ , respectively, at 1 month;  $1.44 \pm 0.66$  vs  $1.14 \pm 0.77$  at 3 months; all  $P < .05$ ) and a higher retear rate (26.67% vs 9.09%;  $P < .05$ ). Based on the results of the correlation analysis, patients who have a higher Sugaya type postoperatively may have more pain than those who have a lower Sugaya type ( $r = 0.361$ ,  $0.377$ ,  $0.395$ , and  $0.334$  at 1, 3, 6, and 24 months, respectively; all  $P < .05$ ). The shoulder function scores, including the Constant-Murley, UCLA, and ASES scores, were not correlated with the vitamin D level. As well, we found no significant differences in function scores between the groups. Our results showed that vitamin D deficiency was prevalent in patients undergoing rotator cuff repair, accounting for 50.56% of cases. Thus, vitamin D deficiency is an important concern for surgeons.

Vitamin D deficiency has become a global health problem. One billion people in the world have a vitamin D deficiency.<sup>17,25</sup> Vitamin D is a kind of steroid produced in the skin by sunlight and is converted into its active form by the hydroxylation process in the liver and kidneys.<sup>25</sup> Vitamin D can promote calcium absorption and regulate circulating

TABLE 6

Correlation Between the Visual Analog Scale (VAS) Score and Types of Retear at Different Time Points<sup>a</sup>

VAS Pain Score	<i>r</i>	<i>P</i> Value
Preoperative	-0.034	.754
1 mo postoperative	0.361	<b>.001</b>
3 mo postoperative	0.377	<b>&lt;.001</b>
6 mo postoperative	0.395	<b>&lt;.001</b>
24 mo postoperative	0.334	<b>.001</b>

<sup>a</sup>Boldface *P* values indicate statistical significance ( $P < .05$ ).

calcium and phosphate levels for normal bone mineralization by the vitamin D receptor.<sup>17</sup> In addition, vitamin D plays an important role in decreasing the inflammatory response by reducing proinflammatory cytokines<sup>3</sup> and promoting protein synthesis and skeletal muscle growth.<sup>9</sup>

Although the correlation between pain and the vitamin D level has been previously investigated under other conditions, this is the first time the relationship between pain and vitamin D level has been reported in patients undergoing arthroscopic cuff repair. This study found that preoperative vitamin D deficiency was associated with early pain after rotator cuff repair. Low vitamin D levels have been reported to be associated with increased pain in observational studies.<sup>16</sup> The mechanisms for vitamin D in pain management are the anti-inflammatory effects mediated by reduced cytokine and prostaglandin release and effects on T-cell responses.<sup>14,24</sup> In vitro studies<sup>25</sup> have shown that vitamin D inhibits the synthesis of prostaglandin E2 (PGE2), which is an essential factor in inflammatory pain.<sup>13</sup> A clinical study<sup>11</sup> found that vitamin D supplementation can reduce musculoskeletal pain with decreased levels of inflammatory cytokines, including PGE2. Thereby, vitamin D plays a vital role in the presence of pain after arthroscopic rotator cuff repair, and vitamin D supplementation may reduce the VAS score of patients who have vitamin D deficiency. However, more randomized, placebo-controlled studies are needed before any conclusions can be drawn.

The correlations between the serum vitamin D level and rotator cuff tear features may be controversial. In 2009, Oh et al<sup>30</sup> investigated the vitamin D levels of 366 patients with rotator cuff injuries and found that vitamin D levels was correlated with fat infiltration of the rotator cuff tissue. This result was consistent with the present study's finding, although the correlation coefficients of both studies were too low ( $<0.3$ ) to suggest clinical significance. In 2015, Ryu et al<sup>34</sup> conducted a cohort study (91 cases) and found that low vitamin D levels were not correlated with the tear size, the extent of retraction, or degree of fatty infiltration in rotator cuff muscles. These different results may have been caused by the research conditions. Unlike the study by Ryu et al, our study excluded massive tears and only assessed the degree of supraspinatus fatty infiltration, which may have reduced statistical errors. The number of cases with a high degree of fatty infiltration (Goutallier stage  $>2$ ) accounted for a very small percentage of cases in previous

studies,<sup>30,34</sup> which may have limited the accuracy of correlation analysis.

The bone-tendon healing process after surgery is very complicated, as it involves many factors, including endogenous cells, cytokines, growth factors, and collagen fibers. The normal rotator cuff tendon footprint area contains 4 layers of structures: the tendon, unmineralized fibrocartilage, mineralized fibrocartilage, and bone tissue. After arthroscopic repair, these structures disappear and are replaced with fibrovascular scar tissue. Vitamin D can induce an increase in the content of type 1 collagen fibers and decrease type 3 collagen fibers, making the healing tendon similar to its original structure.<sup>35</sup> Some animal studies found that by blocking matrix metalloproteinases (MMPs), which can inhibit rotator cuff healing, vitamin D can promote the accumulation of fibrocartilage and collagen and improve tendon healing.<sup>4,5</sup>

The effects of vitamin D deficiency on the retear rate after arthroscopic rotator cuff repair are still unclear. Some animal experiments confirmed that a sufficient vitamin D level promoted tendon-bone healing after rotator cuff repair.<sup>2</sup> Vitamin D can also inhibit MMPs and promote tendon healing.<sup>4,5,9</sup> In *in vitro* experiments, Bahar-Shany et al<sup>3</sup> found that vitamin D can block the expression of MMPs by inhibiting extracellular signal-regulated kinase, c-Jun N-terminal kinase, and the nuclear factor- $\kappa$ B pathway and promote tendon-bone healing. Vitamin D can also inhibit inflammatory factors, such as tumor necrosis factor  $\alpha$ , interleukin 6, and C-reactive protein, to reduce local and systemic inflammatory reactions and relieve postoperative pain.<sup>20</sup> O'Donnell et al<sup>29</sup> analyzed 41,467 patients undergoing rotator cuff repair and found that vitamin D deficiency was significantly related to shoulder revision surgery. Harada et al<sup>15</sup> conducted database research and found that low preoperative vitamin D levels were significantly associated with complications after rotator cuff repair. Ryu et al<sup>34</sup> found that low vitamin D levels were not correlated with retear after arthroscopic rotator cuff repair; however, that study had a shortcoming in that 88% of the patients had vitamin D deficiency. To determine the relationships between serum vitamin D level (sufficiency vs deficiency) and healing status after repair, a certain number of patients with sufficient vitamin D levels are required, which may affect the accuracy of the results. Our result further confirmed that vitamin D deficiency was related to the retear rate after arthroscopic rotator cuff repair.

The treatment of rotator cuff tears has undergone many innovations in the past 30 years,<sup>26,31,32</sup> including surgical techniques, tissue engineering, and biological factors. However, because of the insufficient blood supply of the rotator cuff tissue, scar tissue is the main structure at the tendon-bone healing site after repair.<sup>28</sup> The retear rates after arthroscopic cuff repair are still not low.<sup>22,27,36</sup> Vitamin D as a biological factor may play an increasingly more critical role in the future.

### Limitations

Several limitations of the present study should be mentioned. First, it was a retrospective cohort study, the

sample size was small, and the level of evidence was low. Second, we did not assess some of the factors that can affect tendon-bone healing, such as the degree of overuse, osteoporosis, and sports activities. Third, only the preoperative serum vitamin D level was measured. The vitamin D level may fluctuate during follow-up after surgery. Thus, more clinical and basic studies are needed to identify the relationship between the vitamin D level and rotator cuff diseases.

### CONCLUSION

Our study revealed that preoperative vitamin D deficiency was associated with a higher retear rate and early pain after arthroscopic rotator cuff repair.

### REFERENCES

1. Abtahi AM, Granger EK, Tashjian RZ. Factors affecting healing after arthroscopic rotator cuff repair. *World J Orthop*. 2015;6(2):211-220.
2. Angeline ME, Ma R, Pascual-Garrido C, et al. Effect of diet-induced vitamin D deficiency on rotator cuff healing in a rat model. *Am J Sports Med*. 2014;42(1):27-34.
3. Bahar-Shany K, Ravid A, Koren R. Upregulation of MMP-9 production by TNF $\alpha$  in keratinocytes and its attenuation by vitamin D. *J Cell Physiol*. 2010;222(3):729-737.
4. Bedi A, Fox AJ, Kovacevic D, et al. Doxycycline-mediated inhibition of matrix metalloproteinases improves healing after rotator cuff repair. *Am J Sports Med*. 2010;38(2):308-317.
5. Bedi A, Kovacevic D, Hettrich C, et al. The effect of matrix metalloproteinase inhibition on tendon-to-bone healing in a rotator cuff repair model. *J Shoulder Elbow Surg*. 2010;19(3):384-391.
6. Choi S, Kim MK, Kim GM, et al. Factors associated with clinical and structural outcomes after arthroscopic rotator cuff repair with a suture bridge technique in medium, large, and massive tears. *J Shoulder Elbow Surg*. 2014;23(11):1675-1681.
7. Constant CR, Murley AH. A clinical method of functional assessment of the shoulder. *Clin Orthop Relat Res*. 1987;214:160-164.
8. Davidson JF, Burkhart SS, Richards DP, Campbell SE. Use of preoperative magnetic resonance imaging to predict rotator cuff tear pattern and method of repair. *Arthroscopy*. 2005;21(12):1428.
9. Dougherty KA, Dilisio MF, Agrawal DK. Vitamin D and the immunomodulation of rotator cuff injury. *J Inflamm Res*. 2016;9:123-131.
10. Ellman H, Kay SP. Arthroscopic subacromial decompression for chronic impingement: two- to five-year results. *J Bone Joint Surg Br*. 1991;73(3):395-398.
11. Gendelman O, Itzhaki D, Makarov S, et al. A randomized double-blind placebo-controlled study adding high dose vitamin D to analgesic regimens in patients with musculoskeletal pain. *Lupus*. 2015;24(4-5):483-489.
12. Goutallier D, Postel JM, Gleyze P, et al. Influence of cuff muscle fatty degeneration on anatomic and functional outcomes after simple suture of full-thickness tears. *J Shoulder Elbow Surg*. 2003;12(6):550-554.
13. Grösch S, Niederberger E, Geisslinger G. Investigational drugs targeting the prostaglandin E2 signaling pathway for the treatment of inflammatory pain. *Expert Opin Investig Drugs*. 2017;26(1):51-61.
14. Habib AM, Nagi K, Thillaiappan NB, et al. Vitamin D and its potential interplay with pain signaling pathways. *Front Immunol*. 2020;11:820.
15. Harada GK, Arshi A, Fretes N, et al. Preoperative vitamin D deficiency is associated with higher postoperative complications in arthroscopic rotator cuff repair. *J Am Acad Orthop Surg Glob Res Rev*. 2019;3(7):e075.
16. Helde-Frankling M, Björkhem-Bergman L. Vitamin D in pain management. *Int J Mol Sci*. 2017;18(10):2170.

17. Holick MF. Vitamin D deficiency. *N Engl J Med*. 2007;357(3):266-281.
18. Holick MF, Siris ES, Binkley N, et al. Prevalence of Vitamin D inadequacy among postmenopausal North American women receiving osteoporosis therapy. *J Clin Endocrinol Metab*. 2005;90(6):3215-3224.
19. Kim DM, Shim IK, Shin MJ, et al. A combination treatment of raloxifene and vitamin D enhances bone-to-tendon healing of the rotator cuff in a rat model. *Am J Sports Med*. 2020;48(9):2161-2169.
20. Laird E, McNulty H, Ward M, et al. Vitamin D deficiency is associated with inflammation in older Irish adults. *J Clin Endocrinol Metab*. 2014;99(5):1807-1815.
21. Lee JH, Kim JY, Kim JY, et al. Prevalence of and risk factors for hypovitaminosis D in patients with rotator cuff tears. *Clin Orthop Surg*. 2021;13(2):237-242.
22. Lee KW, Seo DW, Bae KW, Choy WS. Clinical and radiological evaluation after arthroscopic rotator cuff repair using suture bridge technique. *Clin Orthop Surg*. 2013;5(4):306-313.
23. Lee YS, Jeong JY, Park CD, et al. Evaluation of the risk factors for a rotator cuff retear after repair surgery. *Am J Sports Med*. 2017;45(8):1755-1761.
24. Liu X, Nelson A, Wang X, et al. Vitamin D modulates prostaglandin E2 synthesis and degradation in human lung fibroblasts. *Am J Respir Cell Mol Biol*. 2014;50(1):40-50.
25. Looker AC, Johnson CL, Lacher DA, et al. Vitamin D status: United States, 2001-2006. *NCHS Data Brief*. 2011;(59):1-8.
26. Lorbach O, Baums MH, Kostuj T, et al. Advances in biology and mechanics of rotator cuff repair. *Knee Surg Sports Traumatol Arthrosc*. 2015;23(2):530-541.
27. McElvany MD, McGoldrick E, Gee AO, et al. Rotator cuff repair: published evidence on factors associated with repair integrity and clinical outcome. *Am J Sports Med*. 2015;43(2):491-500.
28. Milano G. Biological augmentation in rotator cuff repair: the real challenge for the future of shoulder surgery. *Joints*. 2018;6(3):133-134.
29. O'Donnell EA, Fu MC, White AE, et al. The effect of patient characteristics and comorbidities on the rate of revision rotator cuff repair. *Arthroscopy*. 2020;36(9):2380-2388.
30. Oh JH, Kim SH, Kim JH, et al. The level of vitamin D in the serum correlates with fatty degeneration of the muscles of the rotator cuff. *J Bone Joint Surg Br*. 2009;91(12):1587-1593.
31. Patel S, Gualtieri AP, Lu HH, Levine WN. Advances in biologic augmentation for rotator cuff repair. *Ann N Y Acad Sci*. 2016;1383(1):97-114.
32. Proctor CS. Long-term successful arthroscopic repair of large and massive rotator cuff tears with a functional and degradable reinforcement device. *J Shoulder Elbow Surg*. 2014;23(10):1508-1513.
33. Richards RR, An KN, Bigliani LU, et al. A standardized method for the assessment of shoulder function. *J Shoulder Elbow Surg*. 1994;3(6):347-352.
34. Ryu KJ, Kim BH, Lee Y, et al. Low serum vitamin D is not correlated with the severity of a rotator cuff tear or retear after arthroscopic repair. *Am J Sports Med*. 2015;43(7):1743-1750.
35. Schaer M, Schober M, Berger S, et al. Biologically based strategies to augment rotator cuff tears. *Int J Shoulder Surg*. 2012;6(2):51-60.
36. Sugaya H, Maeda K, Matsuki K, Moriishi J. Functional and structural outcome after arthroscopic full-thickness rotator cuff repair: single-row versus dual-row fixation. *Arthroscopy*. 2005;21(11):1307-1316.
37. Thigpen CA, Shaffer MA, Gaunt BW, et al. The American Society of Shoulder and Elbow Therapists' consensus statement on rehabilitation following arthroscopic rotator cuff repair. *J Shoulder Elbow Surg*. 2016;25(4):521-535.
38. Yamamoto A, Takagishi K, Osawa T, et al. Prevalence and risk factors of a rotator cuff tear in the general population. *J Shoulder Elbow Surg*. 2010;19(1):116-120.