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Comparison of histologic healing and biomechanical characteristics between repair techniques for a delaminated rotator cuff tear in rabbits

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Background: The purpose of this study was to compare histologic healing and biomechanical characteristics between 2 repair techniques (layer by layer, repair of each layer to bone separately; and whole layer, repair of each layer to the bone en masse) for delaminated rotator cuff tear.

Materials and methods: Rabbits were used as subjects and classified into 2 groups: group A, right side, the layer-by-layer repair group; and group B, left side, the whole-layer repair group. Histologic evaluations were done at 3 weeks (n = 7) and 6 weeks (n = 4) after operation. Biomechanical tests to evaluate the tensile property were done at time 0 (n = 5) and 3 weeks (n = 5) after operation.

Results: Histologic healing improved in all groups. A smaller cleft was found between layers in group B compared with the cleft in group A at 3 weeks after operation. At time 0, group A showed a higher yield load and ultimate failure load (67 ± 10.5 N and 80 ± 7.8 N, respectively). However, at 3 weeks after operation, group B showed a higher yield load (48 ± 7.6 N).

Conclusions: In the delaminated rotator cuff tear model in the rabbit, the whole-layer repair showed a narrow gap between layers and a higher yield load at 3 weeks after operation. Surgical techniques that unite the cleft in a delaminated tear could improve biomechanical strength after operation.

Level of evidence: Basic Science Study; Biomechanics and Histology

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Keywords: Delamination; rotator cuff tear; histologic healing; biomechanical; layer-by-layer repair; whole-layer repair

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Delaminated rotator cuff tear is a type of degenerative rotator cuff tear.^{5,7,22,25} Delaminated rotator cuff tears account for 38% to 92% of degenerative rotator cuff tears.^{1,6,10,17,24} This type of tear has some characteristic features. First, retraction can be seen more toward the articular side than toward

the bursal side.^{5,16,17,24,25} Second, intrasubstance cleavage is observed between layers.²⁵ The clinical significance of delamination is its negative prognostic effect on clinical and radiologic outcomes.^{1,6} Although a definite cause for its negative result has not been defined yet, these characteristics are believed to be related to poor results. Therefore, many surgical repair techniques have been introduced and used to solve these characteristic tear patterns and to increase the rate of healing.^{11,16,20,25,27}

Sugaya and colleagues repaired the inner and outer layers of the delaminated rotator cuff to the medial and lateral row separately with double-row repair. They suggested that each layer of the delaminated rotator cuff should be repaired separately on the background that secure repair of the inner layer to the medial footprint area is important to success.^{18,28} On the contrary, Park et al repaired the delaminated rotator cuff tear with an en masse suture bridge repair; the suture is passed through the entire tendon to repair it.²⁰ They suggested that the en masse suture bridge repair technique could unite each layer and decrease shear force. Only one clinical comparison study of these 2 techniques has been published.¹² However, there is a no comparison study on histologic healing and biomechanical properties according to repair techniques in delaminated rotator cuff tear. The purpose of this study was to compare histologic healing and biomechanical characteristics (yield load and ultimate load) between the 2 surgical repair techniques (layer by layer, repair of each layer to bone separately; and whole layer, repair of each layer to the bone en masse) for full-thickness rotator cuff tear with different degrees of retraction between the delaminated layers.

Materials and methods

Study design and surgical methods

This study used 34 adult male New Zealand white rabbits with ages ranging between 12 and 14 weeks and having an average weight of 2.3 kg. We carried out the layer-by-layer repair on the right side (categorized as group A) and the whole-layer repair on the left side (categorized as group B). The animals were anesthetized by an intramuscular injection having a 1:1 mixture of Zoletil (Virbac, Carros, France) and Rompun (Bayer, Leverkusen, Germany). A longitudinal incision of approximately 3 cm was made over the shoulder, and dissection was performed down to the deltoid. The deltoid was retracted bluntly to reveal the supraspinatus tendon. The supraspinatus tendon was then transected at its insertion onto the greater tuberosity. To make the same delaminated rotator cuff tear in each rabbit, we first identified the bicipital groove and the long head of the biceps tendon. We dissected the supraspinatus tendon from the humeral head insertion by using a sharp No. 11 blade at a point 5 mm behind the biceps tendon. After that, we made a bifurcated delaminated tear having a width of 1 cm of the supraspinatus tendon. We set the outer layer to be 3 mm longer than the inner layer to make a similar clinical manifestation (Fig. 1). In group A, the inner and outer layers were repaired separately (layer-by-layer repair technique). In group B, the inner and outer layers were repaired simultaneously by the whole-layer repair technique (Fig. 2). The wound was irrigated and

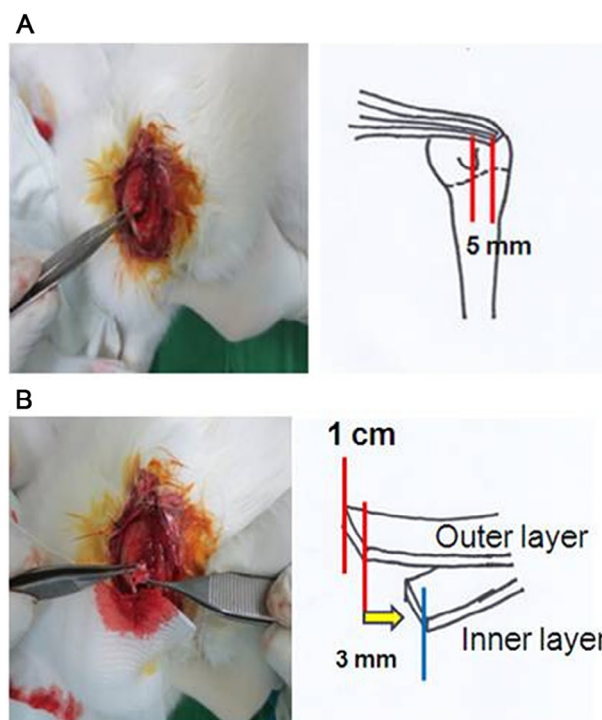


Figure 1 We dissected the supraspinatus tendon from the humeral head insertion at a point 5 mm behind the biceps tendon (A). Then, a bifurcated delaminated tear having a width of 1 cm was created, and the outer layer was made to be 3 mm longer than the inner layer (B).

closed with interrupted, subcutaneous No. 3 Vicryl sutures (Ethicon, Somerville, NJ, USA). In addition, the skin was closed with a running No. 4 Monocryl suture (Ethicon). Among the 34 rabbits, 7 died because of infection. The remaining 27 rabbits were included as final subjects. We allotted 16 rabbits for biomechanical tests and 11 rabbits for histologic evaluations.

Histologic evaluations

We sacrificed 7 rabbits and 4 rabbits at 3 weeks and 6 weeks after the operation, respectively. For sacrifice of the subjects, the animals were sedated with ketamine, xylazine, and atropine, with the dose being different on the basis of the weight of the rabbits. This was followed by a bolus intravenous injection of Rompun 10 mL into the lateral auricular vein.

After the rabbits were sacrificed, the tissues removed from the rabbits were fixed in 10% buffered formalin solution and embedded in paraffin. The target site was resected en bloc, and paraffin blocks were prepared; 5- μ m coronal sections of the humeral head and the attached supraspinatus tendons were placed on the slides. After staining with hematoxylin-eosin and Masson trichrome stain, histologic evaluation was performed. Histologic grading on the tendon-to-bone junction and the delaminated tear portion was analyzed with the Soslowsky score for fibroblast proliferation, inflammation, collagen, and angiogenesis.²⁶ All slides were analyzed by 1 pathologist.

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