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Review article

Clinical results of anterior cruciate ligament reconstruction with ligament remnant tissue preservation: A systematic review

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Abstract

Purpose: To clarify the effects of ACL remnant tissue preservation on the clinical outcome of ACL reconstruction.
Methods: This is a systematic review.
Results: The majority of the reviewed articles suggested that remnant preservation significantly improved knee stability after ACL reconstruction, although there was some controversy. In addition, it was suggested that the degree of initial graft coverage significantly affected postoperative knee stability. Remnant preservation did not increase the occurrence rate of cyclops lesion.
Conclusion: Sufficient coverage of the graft with remnant tissue improves postoperative knee stability without any detrimental effects on the subjective and functional results.
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Keywords: anterior cruciate ligament reconstruction; remnant tissue preservation; remnant-preserving procedure; single-bundle reconstruction; double-bundle reconstruction

Introduction

Arthroscopic single-bundle procedures have been commonly used to reconstruct the injured anterior cruciate ligament (ACL). However, Lewis et al[1] systematically reviewed 1024 outcomes after single-bundle ACL reconstruction, which were previously reported in the randomized clinical trials, and reported that the Lachman test was positive in 59% of the cases, and that the side-to-side differences of the anterior laxity were more than 5 mm in 16% of the cases. One of the final goals of ACL reconstruction is the complete restoration of normal knee stability in all patients. From this viewpoint, many orthopaedic surgeons are not fully satisfied with the clinical results after the commonly performed ACL reconstruction. Therefore, many investigators have made effort to improve the clinical results of single-bundle ACL reconstruction using various approaches.[2–6] One approach is to preserve the ACL remnant tissue during ACL reconstruction, because the remnant tissue preservation has several potential advantages to improve the clinical results of ACL reconstruction: Namely, the remnant preservation may enhance recovery of proprioceptive sensation,[7–10] accelerate cell repopulation and revascularization in the tendon graft,[11] reduce the incidence and the degree of tunnel enlargement,[12] and reconstruct a nearly normal attachment of the graft.[13] Several types of remnant-preserving ACL reconstruction procedures have been developed to date.

In 2000, Adachi et al[2] reported on the first ACL remnant tissue preserving procedure to reconstruct the ACL using the

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over-the-top route method (Figure 1). Although they named this procedure "ACL augmentation", this procedure could be regarded as a remnant tissue-preserving ACL reconstruction procedure for the ACL insufficiency. In 2006, Lee et al[14] reported a remnant-preserving single-bundle procedure for the standard single-bundle ACL reconstruction with a femoral tunnel and a tibial tunnel (Figure 2). A criticism on this procedure is that the remnant tissue was detached from the femoral attachment by a surgeon to visualize the lateral condyle. To solve this issue, Ahn et al[15,16] tried to re-apply a tension to the remnant tissue, which was detached from the femoral attachment, by pulling up the femoral end of the remnant tissue towards the femur with a few PDS threads. Recently, however, Jung et al[17] reported that re-tensioning of the preserved ACL remnant tissue could not improve the results of the remnant-preserving ACL reconstruction. In 2009, Kim et al[18] described a remnant-preserving double-bundle reconstruction procedure, in which one tibial tunnel and 2 femoral tunnels were created, using a split quadriceps tendon-bone graft. A criticism on this procedure is that they also detached the femoral end from the femur or the PCL, similarly as in the above-described Lee's single-bundle procedure. Recently, Yasuda et al[13] reported a remnant-preserving procedure for the standard anatomic double-bundle ACL reconstruction, in which 2 tibial and 2 femoral tunnels were created at the center of the AM and PL bundle attachments (Figure 3A). A specific feature of this procedure in comparison with the previously reported single- and double-bundle procedures is that the proximal attachment of the ACL remnant tissue is not detached from the femur or the posterior cruciate ligament (Figure 3B).

However, it has been unclear about the clinical utility of the remnant tissue preservation in ACL reconstruction. In addition, there has been expectation that the remnant preservation may reduce tunnel enlargement after ACL reconstruction.[13] On the other hand, there has been some apprehension that remnant preservation may increase the occurrence rate of cyclops syndrome, which shows a serious loss of knee extension caused by a hard nodule around the reconstructed ACL, or cyclops lesion, which is a soft synovial tissue mass around the reconstructed ACL without any clinical symptom.[19] Therefore, it is needed to carefully review the previous clinical literature to clarify the effect of the remnant tissue preservation on the clinical outcome of ACL reconstruction. The purpose of this systematic review is to clarify effects of the ACL remnant tissue preservation on the clinical outcome of single- and double-bundle ACL reconstruction. The specific hypotheses are as follows: 1) The ACL remnant tissue preservation may improve the knee stability after single- and double-bundle ACL reconstructions. 2) The degree of initial graft coverage with the ACL remnant tissue may affect the postoperative knee stability. 3) The ACL remnant tissue preservation may not increase the occurrence rate of cyclops lesion. 4) The ACL remnant tissue preservation may reduce postoperative tunnel enlargement.

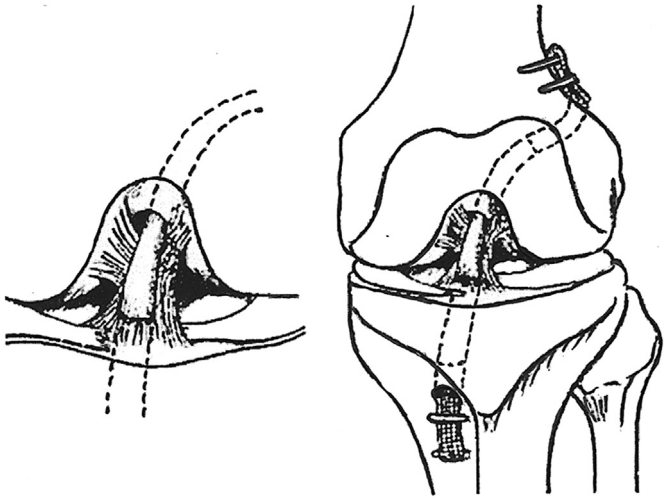

Figure 1. The remnant-preserving single-bundle procedure reported by Adachi et al.[2] An autogenous hamstring tendon graft or an allogenic fascia lata graft was placed through the femoral over-the-top route. (Figure 1 is reprinted from Reference 2 with permission from Springer Science and Business Media.)

Methods

In this systematic review, previous literature on ACL reconstruction with preservation of the ACL remnant tissue was searched in the PubMed database in December 2015, using keywords related to this study's purpose, such as "ACL remnant tissue", "remnant tissue preservation", "ACL reconstruction with remnant preservation", and "remnant tissue preserving ACL reconstruction". A total of 191 articles were identified. After duplicates were removed, 163 articles were screened. A total of 121 articles were excluded because of the following reasons: 73 articles dealing with ligaments different from the ACL and 48 technical or biomechanical articles that did not report any clinical results after ACL reconstruction (Figure 4). Subsequently, 42 full-text clinical articles were assessed for eligibility. The following types of clinical studies were excluded from our review. First, studies that compared a remnant-preserving single-bundle procedure with a remnant-resecting double-bundle procedure were excluded because it was logically impossible to clarify the effect of the ACL remnant preservation on a certain ACL reconstruction procedure. Second, studies on so-called "selective" single-bundle ACL reconstruction[3,20,21] for "isolated" one bundle tear were excluded because the preserved ACL tissue was not regarded as the "remnant" tissue in these procedures. Thus, we selected 10 articles in which the clinical results of a remnant-preserving ACL reconstruction procedure were compared with those of the same ACL reconstruction procedure without remnant tissue preservation, in order to detect the effect of the remnant tissue preservation on the ACL reconstruction (Figure 4).

Results

1 Does ACL remnant tissue preservation improve clinical outcome and knee stability after ACL reconstruction?

Hong et al[22] conducted a randomized controlled trial using 90 consecutive patients to compare the clinical outcome of single-bundle ACL reconstruction using an allograft between

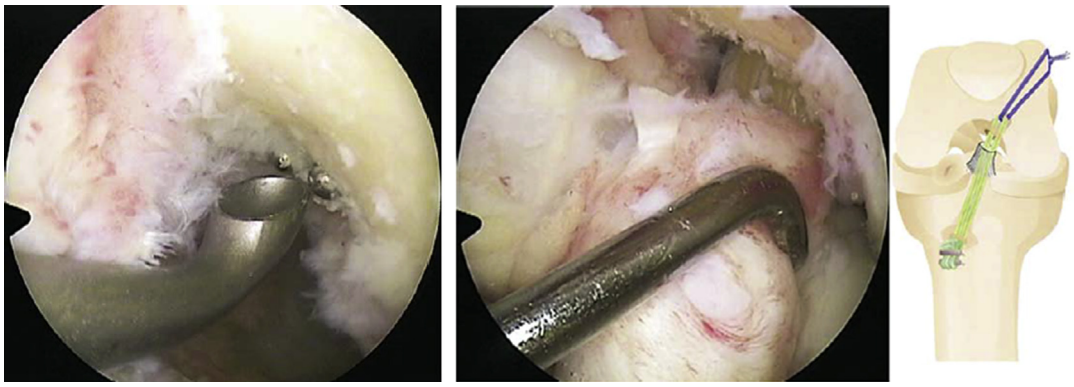

Figure 2. The remnant-preserving single-bundle procedure reported by Lee et al.[14] The doubled hamstring graft was placed into the femoral and tibial tunnels, penetrating the tibial remnant. However, the remnant tissue was detached from the femoral attachment to create the femoral tunnel. (Figure 2 is reprinted from Reference 14 with permission from Elsevier.)

remnant-preserving and remnant-resecting procedures. They reported that there were no significant differences in the clinical outcome in terms of knee stability, other clinical measures, and proprioception recovery (Table 1). Recently, however, Takazawa et al[23] divided a total of 218 patients who had identifiable ACL remnant tissue into 2 groups: 85 patients in whom the remnant was preserved as much as possible and 98 patients in whom the remnant was not preserved. In the results, the side-to-side anterior laxity of the knee was significantly better in the remnant-preserved group than in the remnant-resected group (Table 1). They also described that the occurrence rate of ACL graft rupture in group 1 (1.1%) was significantly less than that in group 2 (7.1%). On the other hand, there were no significant differences in the other clinical measures. Nakamae et al[24] described that the side-to-side anterior laxity after the remnant preserving single-bundle procedure (the mean, 0.4 mm) was significantly better that after the remnant resecting procedure (1.3 mm) (Table 1), while no significant difference in the Lysholm score or pivot-shift test was seen between the three groups.

Concerning anatomic double-bundle procedures, Kondo et al[25] recently reported a prospective clinical study using 179 patients to evaluate the remnant-preserving anatomic double-bundle procedure (Figure 3) reported by Yasuda et al[13] in comparison with the standard anatomic double-bundle ACL reconstruction without the remnant preservation. In the follow-up evaluation, the side-to-side laxity was significantly less in in the preserved group than in the resected group (Table 1). In addition, they compared the postoperative knee laxity of these 2 groups using the chi-square test, and found that the remnant-preserved group was significantly better than the remnant-resected group (Table 1). The results of the pivot-shift test was also significantly better in the preserved group (89% were negative) than in the resected group (78%). They concluded that remnant preservation in anatomic double-bundle ACL reconstruction significantly improved post-operative knee stability, although it did not significantly improve subjective and functional results in the short-term evaluation.

Thus, in this review, we should recognize that the remnant-preserving procedures used in the previous articles included a wide variation. Nevertheless, the majority of the reviewed article suggested that the ACL remnant tissue preservation significantly improved the knee stability after ACL reconstruction, although there is some controversy. On the other hand, the subjective and functional clinical results are comparable between the remnant tissue–preserving and resecting procedures.

2 Does the degree of initial graft coverage with ACL remnant tissue affect postoperative knee stability?

Some previous studies have compared the postoperative knee laxity between sufficiently and insufficiently preserved subgroups after remnant-preserving ACL reconstruction. Lee et al[26] divided 16 patients with single-bundle reconstruction into 2 groups, Group I ($n = 9$) with an ACL remnant of more than 20% and Group II ($n = 7$) with less than 20%. They reported that there was no significant difference in the knee stability between the 2 groups (Table 2). However, the number of the subjects was too small to make a statistical comparison. Kim et al[27] divided 66 consecutive patients with single-bundle reconstruction into 2 groups according to whether the remnant ACL fibers could be preserved by over 50% or not, and found that the result of the pivot shift test was significantly better in the former group than in the latter group, although they could not find any significant difference in the side-to-side laxity measurement between the 2 groups (Table 2). Muneta et al[28] described that the postoperative knee stability after the remnant-preserving double-bundle reconstruction showed a weak correlation with the volume of the ACL remnant (Table 2). These studies, however, had a logical flaw in their study designs: namely, these studies did not include a group in which the remnant tissue was completely resected.

Recently, Kondo et al[25] reported a prospective comparative study with the study design that solved these flaws. Namely, they analyzed the effect of the degree of initial graft coverage on the knee stability in 179 patients who underwent anatomic double-bundle ACL reconstruction. Namely, they divided the

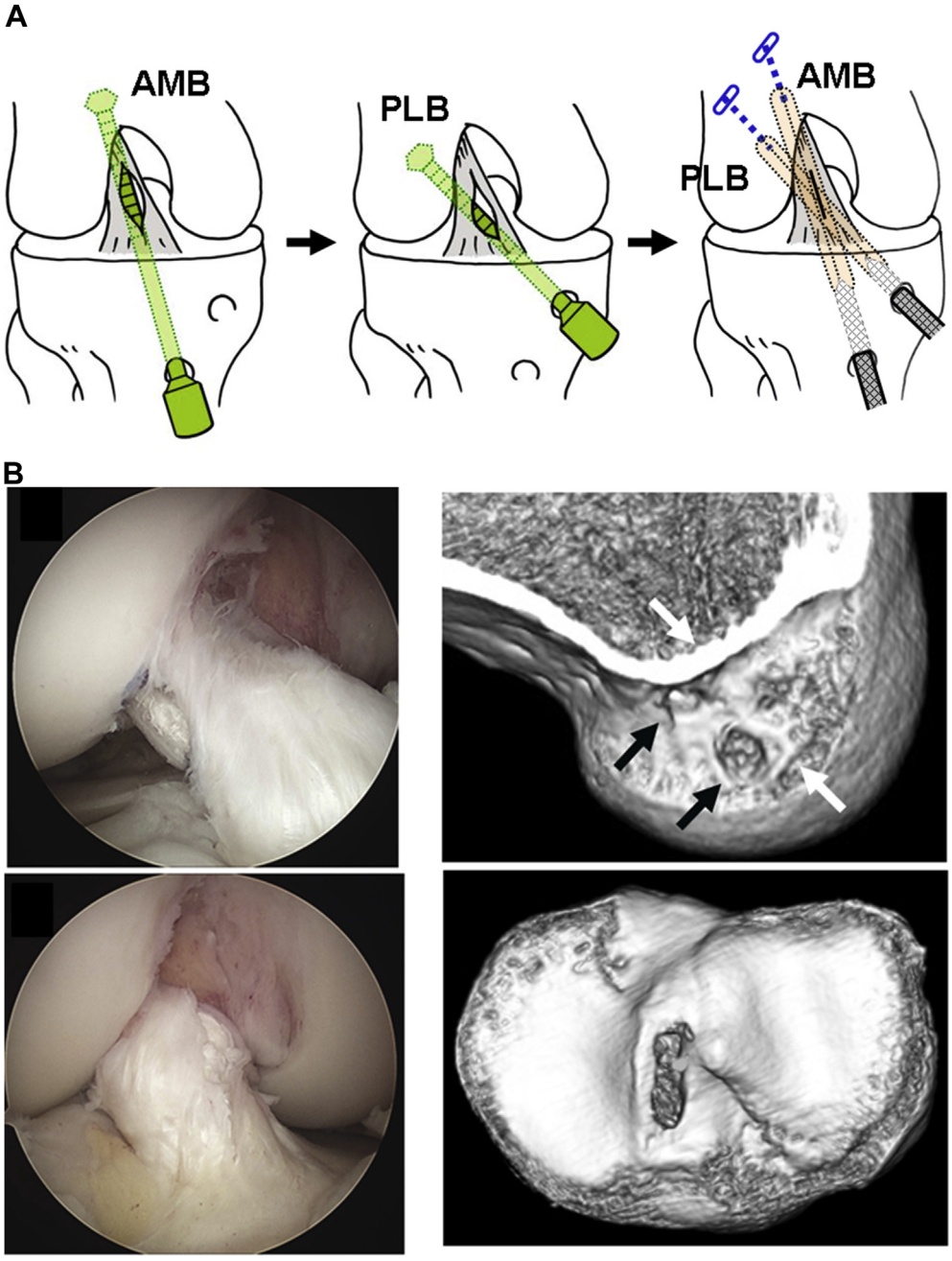

Figure 3. (A) Anatomic double-bundle procedure with preservation of the ACL remnant tissue, reported by Yasuda et al.[13] The two tendon grafts were placed into the tunnels, penetrating the ACL remnant tissue. (B) Because the proximal attachment of the ACL remnant tissue was not detached from the femur or the PC, the two tendon grafts were sufficiently enveloped by the remnant tissue. Each tunnel location was identical with that created in the original anatomic double-bundle procedure. (Figure 3B is reprinted from Reference 13 with permission from Elsevier.)

patients into 3 groups: remnant-resected (RR) group, "insufficiently preserved (IP)" group in which 49% or less of the graft surface was covered with the remnant tissue at the end of ACL reconstruction, and "sufficiently preserved (SP)" group in which 50% or more of the graft surface could be covered with the remnant tissue. They showed a significant correlation between the laxity and the degree of the initial graft coverage, using the Spearman ranked correlation analysis (Table 2). In addition, the ANOVA showed significant differences among the 3 groups, and the post hoc test indicated that the side-to-side laxity in the SP group (mean, 0.7 mm) was significantly better than that in the RR group (mean, 1.5 mm) (Table 2). They also described that this conclusion was supported by their second-look arthroscopic observations: namely, the remnant-preserving procedure was significantly better than remnant-resecting procedure concerning postoperative laceration or tear of the grafts as well as the synovial and fibrous tissue coverage of the grafts.

Thus, we should pay attention to the Kondo's study with a logically appropriate study design, which showed that the

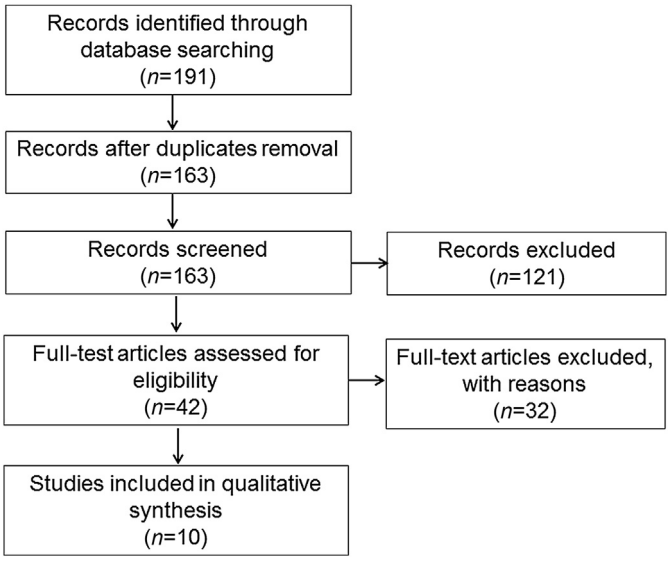

Figure 4. A flow diagram for this systematic review.

Table 1
The effect of ACL remnant tissue (RT) preservation on knee stability after ACL reconstruction.

Authors	Side-to-side knee laxity (mm)		Comparisons
	RT-preserved group	RT-resected group	
Hong et al[22] (single-bundle)	1.6 ± 1.7 ($n = 39$)	1.8 ± 1.8 ($n = 41$)	Not significant
Takazawa et al[23] (single-bundle)	1.0 ± 0.8 ($n = 85$)	1.3 ± 1.0 ($n = 98$)	$p < 0.05$
Nakamae et al[24] (single-bundle)	0.4 ± 1.5 ($n = 73$)	1.3 ± 2.0 ($n = 61$)	$p = 0.013$
Kondo et al[25] (double-bundle)	0.9 ± 2.0 ($n = 81$)	1.5 ± 1.5 ($n = 98$)	$p = 0.0277$
<1 mm	43 patients	33 patients	$p = 0.0321$[a] (χ^2 test)
>1 mm and <3 mm	25 patients	44 patients	
>3 mm	13 patients	21 patients	

Mean ± standard deviation; n = number of patients.
[a] The patients' side-to-side laxity values were divided into 3 categories, <1 mm, >1 and <3 mm, and >3 mm. The χ^2 test showed a significant difference.

degree of initial graft coverage significantly affects postoperative knee stability. This result is reasonable from the biological view point. We consider that some controversy on this issue among the previous articles may be caused by the quality of the study design.

3 Does ACL remnant tissue preservation increase the occurrence rate of cyclops lesion?

In this review, the cyclops syndrom caused by the remnant tissue preservation was not reported at all. Concerning the cyclops lesion, Ahn et al[29] compared 41 patients who underwent the remnant-preserving ACL reconstruction with another 41 patients who had the same reconstruction without the remnant preservation, using postoperative magnetic resonance imaging (Table 3). There was no difference in the occurrence rate of the cyclops lesion detected between the remnant-preserved and resected groups (4.9% and 7.3%, respectively). Cha et al[30] reported a similar comparative MRI study. They compared 100 patients who underwent the remnant-preserving ACL reconstruction with 36 patients who underwent the same ACL reconstruction without preservation of the remnant tissue (Table 3). There was no difference in the prevalence of the cyclops lesion between the remnant-preserved and resected groups (12.2% and 15.0%, respectively). Recently, Kondo et al[25] compared an occurrence rate of the cyclops lesion between the remnant-preserving and resecting procedures in anatomic double-bundle reconstruction, using arthroscopic observation (Table 3), and showed no significant difference in the rate between the 2 procedures (14.5% and 17.4%, respectively).

Thus, these studies showed that preservation of the ACL remnant tissue in ACL reconstruction does not increase the frequency of not only the cyclops syndrome but also the cyclops lesion after ACL reconstruction. Additionally, these study suggests that the occurrence rate of cyclops lesion is comparable between the single- and double-bundle procedures.

Table 2
The effect of the degree of initial graft coverage with ACL remnant tissue on postoperative knee stability.

Authors	Side-to-side knee laxity (mm)		Comparisons
Lee et al[26] (single-bundle)	More than 20% ($n = 9$)	2.3 ± 0.3	NS
	Less than 20% ($n = 7$)	2.4 ± 0.4	
Kim et al[27] (single-bundle)	More than 50% ($n = 36$)	1.9 ± 0.5	NS[a]
	Pivot grade 0	25 patients	$p = 0.039$[b]
	Pivot grade 1	10 patients	
	Pivot grade 2	1 patients	
	Less than 50% ($n = 30$)	2.0 ± 0.5	
	Pivot grade 0:	12 patients	
	Pivot grade 1:	16 patients	
	Pivot grade 2:	2 patients	
Muneta et al[28] (double-bundle)	Well preserved ($n = 32$)	0.7 ± 1.3	$p < 0.05$[c]
	Moderately preserved ($n = 26$)	1.3 ± 1.4	
	Less preserved ($n = 30$)	1.8 ± 1.3	
Kondo et al[25] (double-bundle)	More than 50% ($n = 57$)	0.7 ± 2.1[d]	$p = 0.0373$[d]
	Less than 49% ($n = 24$)	1.3 ± 2.0	
	Resected ($n = 98$)	1.5 ± 1.5	$p = 0.0229$[e]

[a] There was no significant difference (NS) in the side-to-side knee stability between the 2 groups.
[b] There was a significant difference in the pivot shift test result between the 2 groups.
[c] There was a significant difference between the "well" and "less" preserved groups.
[d] There was a significant difference between the "more than 50%" and "resected" groups.
[e] There was a significant correlation among the 3 groups (Spearman ranked correlation analysis).

4 Does remnant tissue preservation reduce postoperative tunnel enlargement?

Zhang et al[12] investigated the effect of remnant preservation on tibial tunnel enlargement in a single-bundle ACL reconstruction with a hamstring autograft. Sixty-two patients were randomly divided into two groups, the remnant-

Table 3
The effect of ACL remnant tissue preservation on the occurrence rate of cyclops lesion. There was no significant difference (NS) between the 2 groups.

Authors	Occurrence rate of cyclops lesion			Comparisons
Ahn et al[29] (single-bundle)	Preserved group	($n = 41$)	4.9%	NS
	Resected group	($n = 41$)	7.3%	
Cha et al[30] (single-bundle)	Preserved group	($n = 100$)	12.2%	NS
	Resected group	($n = 36$)	15.0%	
Kondo et al[25] (double-bundle)	Preserved group	($n = 100$)	14.5%	NS
	Resected group	($n = 36$)	17.4%	

preserving group and the remnant-resecting group, and were followed up for 24 to 27 months. Enlargement of the tibial tunnel was more frequently observed in the remnant-resecting group (the mean, 58.3 %) than in the remnant-preserving group (29.6 %), while the difference was statistically significant. Also the degree of tibial tunnel enlargement was significantly greater in the remnant-resecting group (34.0 %) than in the remnant-preserving group (25.7 %). This study suggested that remnant preservation in ACL reconstruction can reduce tibial tunnel enlargement. However, we could find only one paper concerned with this issue. Further long-term follow-up studies are needed in the near future.

Discussion

The first hypothesis tested in this review is that the ACL remnant tissue preservation may improve the knee stability after ACL reconstruction. The majority of the reviewed article suggested that the ACL remnant tissue preservation significantly improved the knee stability after ACL reconstruction without any detrimental effect as to subjective or functional results, although there was some controversy. There is a possibility that the controversy is caused by a wide variation of the remnant-preserving procedures used in the previous studies. For example, many procedures detached the remnant tissue from the femur or the PCL, and the other procedures did not. In addition, many studies used single-bundle procedures, and the others used anatomic double-bundle procedures. Therefore, the effect of the remnant tissue preservation may be different between these procedures because of the biological or biomechanical difference between the precedures.[13] Therefore, when systematic reviews and meta-analyses will be conducted in the near future, the wide variation in the previously reported remnant-preserving procedures should be recognized as one of the significant problems for the analysis.

Secondly, this review suggested that the degree of initial graft coverage with the ACL remnant tissue significantly affects the postoperative knee stability after single- and double-bundle ACL reconstruction, although there was some controversy. There is a possibility that the controversy is caused by the logical flaw in the study design: namely, the comparison was made in the patients who underwent the remnant-preserving procedure. Therefore, it was noted that Kondo et al[25] found a significant correlation between the laxity and the degree of the initial graft coverage in the logical study design including the remnant-resected group. In the clinical field, there has been a common belief that preservation of the ACL remnant tissue may always prove to be effective. However, there is a strong possibility that the common belief may be disproved in future randomized controlled studies. In addition, this result may explain an additional reason of the above-described controversy concerning the first hypothesis among the previous articles. Namely, the degree of graft coverage varied among all the surgeries performed in the reported studies, because the degree of initial graft coverage after surgery was affected not only by the initial quantity and quality of the ACL remnant tissue but also the surgical techniques. Furthermore, this fact suggested that the quantity and quality of the preserved remnant tissues should be included in the indications of the remnant-preserving procedures, which will be established in the near future. The initial graft coverage also should be precisely evaluated and quantitatively shown in detail as one of the important background factors in future studies that evaluate the clinical outcome of remnant tissue-preserving ACL reconstruction.

Thirdly, this review showed that the ACL remnant tissue preservation does not increase the occurrence rate of not only cyclops syndrome but also cyclops lesion. Namely, all the previously published articles reported that the frequency of intra- and post-operative complications including the cyclops syndrome was comparable between the remnant−preserving and resecting procedures. In addition, the occurrence rate of cyclops lesion was comparable between the single- and double-bundle procedures. In the articles reviewed in the present study and other articles,[31−33] the incidence of cyclops syndrome has been reported to range from 2% to 11%, and the incidence of a cyclops lesion has been reported to range from 2% to 47%. Therefore, it is considered that the variations of the incidence is not caused by preservation of the remnant tissue but other technical or pathological conditions. Fourthly, in this review, we could find only one paper that studied whether the ACL remnant tissue preservation reduced postoperative tunnel enlargement. This article suggested that there is a possibility that remnant preservation in ACL reconstruction reduced tibial tunnel enlargement. The possible reason may be that the preserved remnant tissue may reduce infiltration of the joint liquid into the tunnel and micro-movement of the tendon graft at the tunnel outlet.[13] However, we cannot reach a definite conclusion, because the number of the studies is insufficient.

This review showed that the short-term subjective and functional clinical results were comparable between the remnant tissue−preserving and resecting procedures. In each study, however, this fact did not mean that the normal knee laxity was obtained by the remnant−preserving or resecting procedure. On the other hand, this review suggested that the ACL remnant tissue preservation has potential to significantly improve the postoperative knee stability without any detrimental effect as to subjective or functional results. There may be a criticism that a slight improvement in the averaged knee

laxity is not clinically meaningful for the patient, even though it is statistically significant. However, the averaged improvement value does not mean that the postoperative knee laxity was improved by the value in each knee alone. Kondo et al,[25] described that the averaged improvement value in the remnant-preserved group could be regarded as a result that the remnant-preserving procedure could significantly increase the number of the knees with normal knee laxity. "Less than normal" knee stability may cause meniscal injuries and osteoarthritic changes in the long term after ACL reconstruction, resulting in reduction of functional results. Therefore, one of the final goals of ACL reconstruction is to restore the completely normal knee stability in all patients. As a step to reach the final goal of ACL reconstruction, the above-described significant improvement in knee stability is meaningful in the clinical outcome of ACL reconstruction. Namely, the significant superiority in knee stability may affect the long-term clinical results, resulting in possible superiority in future subjective and functional evaluations. In addition, we should recognize that all of the patients who underwent ACL reconstruction simply hoped to achieve the same stability and functionality as in their contralateral knee.

Why was postoperative knee stability significantly improved by sufficient preservation of the ACL remnant tissue? A few potential mechanisms can be considered. The first potential mechanism is that remnant preservation in ACL reconstruction may accelerate graft remodeling of the graft, resulting in early restoration of the mechanical properties of the graft. It is known that repopulation of cells and revascularization in the graft occurs slowly in remnant-resected ACL reconstruction.[34,35] On the other hand, the ACL remnant tissue has good subsynovial and intrafascicular vascularity.[9] Recently, Xie et al[36] reported that mRNA levels of COLlAl, COL3A1, TGF-b1, VEGF, and GAP-43 in the repopulated cells were significantly increased by the remnant preservation at 6 or 12 weeks, using a rabbit model. Wu et al[37] described that blood flow in the graft was significantly higher in the remnant-preserved group than in the remnant-resected group in their experimental study using rabbits. Most recently, Takahashi et al[38] reported that the remnant preservation significantly accelerated cell repopulation and revascularization in the graft at 6 and 12 weeks after surgery in their study with a sheep model. Secondly, previous animal studies have shown that, in remnant resected ACL reconstruction, the tibial attachment of the tendon graft was narrow and had a different shape in comparison with the normal attachment.[39] On the other hand, recently, Kondo et al[25] pointed out that the reconstructed tibial attachment, which was widely spread on the tibia, appeared to be almost normal in the second-look arthroscopic observations at 1 year after the remnant-preserving reconstruction. Also in an experimental study with a sheep model, Takahashi et al[38] reported that the normal enthesis structure in the ACL attachment was maintained at 12 weeks, and that the remnant tissue was reorganized as a ligamentous tissue after the tissue was adhered to the tendon graft at 4 weeks. Therefore, the second potential mechanism is that, in the remnant-preserving procedure, reconstruction of the broad attachment of the ACL and reorganization of the remnant tissue as a ligamentous tissue may contribute to restoration of the complex function of the normal ACL, resulting in significant improvement of postoperative knee stability when compared with a remnant-resecting procedure. On the other hand, the remnant preservation has been expected to enhance the recovery of proprioceptive sensation.[9,10] Recently, Takahashi et al[38] performed an experimental study with a sheep model and reported that the preservation of the ACL remnant tissue significantly increased the number of mechanoreceptors in the reconstructed ACL at 4 and 12 weeks. In previously reported clinical studies, however, it remains unclear whether restoration of the proprioceptive functions were enhanced by the remnant tissue preservation. Further studies to evaluate postoperative recovery of proprioceptive sensation should be conducted in the near future.

There are some limitations in this study. First, studies with low level of evidence were included in this review. Second, for each of the enrolled study, the surgical techniques and evaluation protocols were inconsistent. Third, we found that the number of available studies, which compared the clinical results between a remnant-preserving ACL reconstruction procedure and the same procedure without remnant tissue preservation, were not sufficient. Beyond these limitations, however, we believe that this review provides valuable information that is useful to understand the current status of the clinical studies concerning the effect of the ACL remnant preservation, and it can contribute to designing future clinical studies that intend to clarify this effect in more detail.

In conclusion, first, the majority of the reviewed article suggested that the ACL remnant tissue preservation significantly improved the knee stability after ACL reconstruction without any detrimental effect as to subjective or functional results, although there was some controversy. Secondly, this review suggested that the degree of initial graft coverage with the ACL remnant tissue significantly affects the postoperative knee stability after single- and double-bundle ACL reconstruction, although there was some controversy. Thirdly, this review showed that the ACL remnant tissue preservation does not increase the occurrence rate of not only cyclops syndrome but also cyclops lesion. In the near future, however, further randomized comparative trials should be conducted, taking the results of the present study into consideration.

Conflicts of interest

The authors declare that they have no conflicts of interest.

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