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Comparison of Revision Surgery With Primary Anterior Cruciate Ligament Reconstruction and Outcome of Revision Surgery Between Different Graft Materials

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Background: The number of primary anterior cruciate ligament reconstructions is increasing rapidly; the number of failing grafts and need for revision surgery have also risen.

Hypothesis: Revision anterior cruciate ligament reconstruction will produce similar results to those of primary reconstruction, and there may be different results according to graft materials.

Study Design: Case control study; Level of evidence, 3.

Methods: Fifty-nine revision surgeries were performed at 1 institution between January 1997 and October 2005. Fifty-five patients (56 operations) were followed. The results of 117 patients (117 knees) treated with arthroscopic primary anterior cruciate ligament reconstruction using double-looped semitendinosus and gracilis autograft from September 2001 to November 2002 were also evaluated. Clinical and stability results between primary and revision anterior cruciate reconstruction were compared. For the revision surgery, 21 (37.5%) knees had revision reconstruction with previously unharvested ipsilateral double-looped semitendinosus and gracilis autograft. Twenty (35.7%) were bone–patellar tendon–bone allograft, and 15 (26.8%) were Achilles allograft. The details of the technique varied according to the original graft choice and the abnormality encountered. Concomitant procedures were necessary in 32 (57.1%) of 56 knees. Clinical and stability results according to the different graft materials were also compared.

Results: There were significant improvements in the scores for subjective, objective forms ($P < .001$), and stability ($P < .001$). However, the clinical results of revision surgery were inferior to primary reconstruction ($P < .001$), but as regards stability, the difference between primary and revision cases was not significant ($P = .338$). There was no difference in clinical and stability results in different groups of graft material ($P = .160$-$.690$).

Conclusion: Revision anterior cruciate ligament reconstruction could improve clinical and stability results, but the clinical results were inferior to those of primary reconstruction. This study also demonstrated that the success of the operation did not depend on the choice of graft materials.

Keywords: knee; anterior cruciate ligament (ACL); revision; reconstruction; autograft; allograft

Increases in leisure time and sporting injuries have led to a rapid increase in the number of primary ACL reconstructions. Consequently, the number of failing grafts and need for revision surgery have also risen.[29] There are no universally accepted criteria for definition of failure. Four main categories of failure include arthritis and pain problems, loss of motion, extensor mechanism dysfunction, and recurrence of laxity.[18] Most clinical follow-up studies report a failure rate of between 10% and 20%, although the prevalence of failure is difficult to determine because of a lack of uniformity in the definition of a failure.[4,7,8,13,28,35] Reports in the literature quote inferior results for revision cases when compared with primary ACL reconstruction.[17,22] However, with the numerous categories of failure, the population of

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failed ACL reconstruction is a diverse group and a hard subset to study. A variety of graft sources have been described for revision surgery depending on multiple factors, including the source of autogenous tissue, type of graft used at primary ACL reconstruction, and surgeon's preference. Some previous studies have reported various results with respect to the specific graft used, but there are few reports on the comparison between different graft materials.[11,14,18,25] The purposes of this study were (1) to compare the clinical and stability results between primary and revision ACL reconstruction and (2) to compare the results of revision surgery between different graft materials.

MATERIALS AND METHODS

Demographics

This retrospective study included 55 patients (56 operations) who were available for follow-up among 59 operations between January 1997 and October 2005. The 3 excluded patients included 2 who had combined posterior cruciate ligament reconstruction and 1 who was unable to attend more recent follow-up because that patient had moved abroad or far from our institute. There were 43 men and 12 women, and the mean age at the time of revision was 31.6 years (range, 21-55 years). The mean time from the primary ACL reconstruction was 52.8 months (range, 5-216 months), and the mean follow-up period was 48.7 months (range, 22-120 months). Fifty-two primary ACL reconstructions (92.9%) had been done by other surgeons with use of 15 Achilles allografts, 14 bone–patellar tendon–bone (BPTB) allografts, 9 BPTB autografts, 5 artificial ligaments, 5 double-looped semitendinosus and gracilis autografts, and 4 Achilles autografts. The remaining 4 cases were our own patients who had undergone reconstruction with BPTB autografts. Among our 4 patients, 3 patients were revised because of traumatic rerupture, and 1 patient was revised because of infection. Graft selection was individualized by factors such as age, activity level, economic status, previous surgery, and surgeon's preference.[15] We prefer to use double-looped semitendinosus and gracilis autograft because we obtained better results in terms of ligamentization from our series of second-look arthroscopies.[3] Therefore, double-looped semitendinosus and gracilis autografts have mainly been used since 2000 because the cross-pin has been available since 2000 in our country. However, BPTB allograft was used in the case of athletes because of rapid bone-to-bone healing and Achilles allograft in the case of tunnel widening because of the additional bone graft with remnant bone. Twenty-one (37.5%) knees had revision reconstruction with previously unharvested ipsilateral double-looped semitendinosus and gracilis autografts. Twenty (35.7%) were BPTB allografts, and 15 (26.8%) were Achilles allografts. For the primary ACL reconstruction, we evaluated a series of 117 consecutive patients who underwent arthroscopic ACL reconstruction using double-looped semitendinosus and gracilis autografts fixed with 2 bioabsorbable cross-pins on the femoral side from September 2001 to November 2002. The interval between injury and surgery was 32.8 months on average (range, 1-180 months), depending on visiting time at our hospital, and mean age was 29.1 years (range, 15-54 years). The mean follow-up period was 26.9 months (range, 25-32 months).

Surgical Procedure and Rehabilitation

All patients were examined under general anesthesia (Lachman test, pivot-shift test, varus and valgus stress test, posterolateral instability test), after which routine diagnostic arthroscopy was performed. Meniscal injury and articular cartilage lesion were evaluated and, if necessary, meniscectomy or meniscal repair and treatment for a cartilage lesion (chondroplasty or microfracture) were performed. We tried to preserve knee joint stability by saving the meniscus as much as possible. Four-strand hamstring tendon grafts were prepared from harvested semitendinosus and gracilis tendons. The ACL reconstruction was done using a transtibial technique. The tibial tunnel was made with an ACL tibial guide (Linvatec, Largo, Fla) set at a 45° to 50° angle, and the femoral tunnel was made from 10:30 to 11 o'clock for the right knee and 1 to 1:30 for the left knee with a femoral guide through the transtibial tunnel. After the tibial tunnel was made, a reamer 1 to 1.5 mm smaller than the graft diameter was introduced, and the femoral tunnel was made to a depth of 35 mm at 1 to 2 mm before the posterior cortex. A dilator was then used to make the tunnel size equal to the graft diameter. After the surgeon confirmed the insertion place of Rigidfix cross-pins (RIGIDfix system, Mitek, Johnson & Johnson, Norwood, Mass) with temporary insertion of wire, the hamstring autograft was inserted. Femoral fixation was made using 2 cross-pins, and all grafts were tensioned with the knee in full extension with 20 lb of force applied by tensiometer before final tibial interference screw fixation. Additional distal tibial post tie fixation was done in all cases (Figure 1).[1] For the revision surgery, the surgical technique was dictated by the status of the failed primary procedure, but it was similar to that used for primary ACL reconstruction. The details of the technique varied according to the original graft choice and the abnormality encountered. Staged operations were performed in 2 knees because of a dilated femoral tunnel, and 3 knees were reconstructed with 1-stage bone graft at the wide tibial tunnel with residual Achilles bone or autoiliac bone graft. During the revision reconstruction, care was taken to correct the tibial and femoral tunnel positions, and the femoral tunnel was made at the most posterior point possible. We routinely removed the hardware but preserved the previous remnant graft if possible. The primary tunnel was reused if the position of the tunnel was correct. If there was some tunnel widening after the bone graft, 1-stage or 2-stage operation was performed according to the severity of tunnel widening. In cases of completely incorrect tunnel placement, a new tunnel was created at the correct position. The most difficult cases were those with incompletely incorrect tunnel position. A small tunnel was first made and was then dilated with a dilator (Linvatec) to avoid a large bone defect and to preserve the original graft remaining after this procedure.

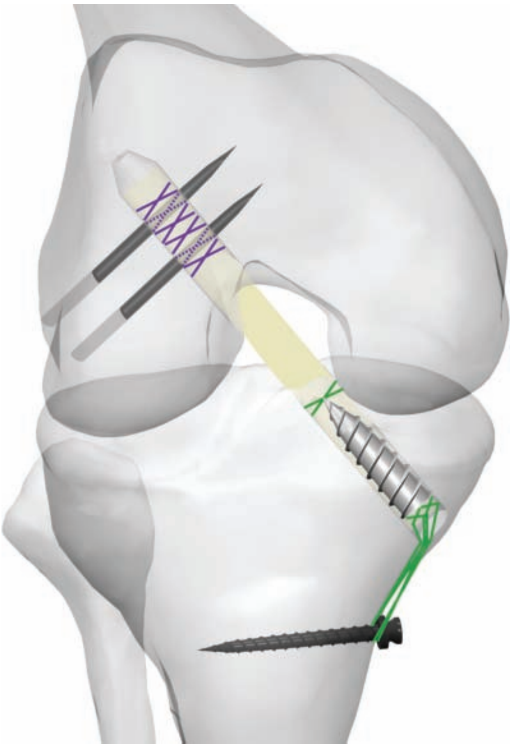

Figure 1. The reconstructed ACL using 4-strand hamstring tendon graft and its fixation. Femoral side, bio–cross-pin; tibial side, bio-interference screw plus post tie fixation.

We used interference screws in the case of a BPTB or Achilles allograft. Concomitant procedures were necessary in 99 of 117 knees (84.5%) during primary reconstruction and 32 of 56 knees (57.1%) during revision surgery, and we counted each component individually if there were combined problems (Table 1). The postoperative regimen did not vary based on revision technique or concomitant operation and was similar to the regimen after primary reconstruction because rehabilitation of the primary ACL reconstruction using double-looped semitendinosus and gracilis autograft was originally slower than with a BPTB or Achilles allograft. Some patients began immediate isometric quadriceps and active range of motion exercise. The third day after surgery, we allowed partial weightbearing within tolerable range. The fourth day after surgery, an ACL brace was put on, and range of motion was increased by 15° increments per week. At 4 weeks after surgery, 90° of motion was allowed, and at 6 weeks after surgery 135° of motion was allowed. At 6 months after surgery, straight-line running was allowed, and at 9 months after surgery, changing direction while running was allowed. However, we prescribed protected weightbearing for 6 to 8 weeks in patients with tunnel widening or bone graft.

Assessment

We routinely checked knee function at preoperative and postoperative periods, and the same methods were used in the assessment of the primary and revision surgeries. To eliminate surgeon bias, a review of the chart and recording of the data were performed by 2 sports medicine fellows who were independent of the treating surgeon. Clinical evaluation was based on Lysholm score and International Knee Documentation Committee (IKDC) measurement criteria. The evaluation for instability was based on KT-2000 arthrometer (MEDmetric Corp, San Diego, Calif) with maximal manual displacement, Lachman test, and pivot-shift test. Standard anteroposterior and lateral plain radiographs at final evaluation were analyzed by a single person. Progression of osteoarthritis was evaluated according to a modified Fairbank scale by comparison of the preoperative and follow-up radiographs (standard anteroposterior and lateral plain radiograph) (Table 2).[10] We divided patients into 2 subgroups (mild group, grade 0 and 1; severe group, grades 2, 3, and 4) according to the prerevision status of the radiograph and compared the clinical results.

TABLE 1
Combined Injuries

	Primary		Revision	
Combined Injuries	n	%	n	%
Meniscal tear				
Medial	80	61.5	27	48.2
Lateral	42	35.9	14	25
Instability				
Medial	5	4.3	2	3.6
Lateral	2	1.7	1	1.8
Posterolateral	2	1.7	2	3.6
Chondral lesion	24	20.5	12	21.4
Loose body	3	2.6	2	3.6

Statistical Methods

Power analysis was performed. If the difference of subjective scores was more than 10 points and KT-2000 arthrometer result more than 2 mm, they showed clinically different results. The alpha (.05) and power (.8) effect size for subjective score (IKDC and Lysholm) and effect size for KT-2000 arthrometer were 2.1739 and 0.2702, respectively. The required sample size was 10 cases for each group. So, our sample size was enough to compare between 3 groups.

Statistical analysis was conducted using SPSS 11.0 (SPSS, Chicago, Ill). For data analysis before and after surgery, Wilcoxon signed rank and χ^2 tests were used. Comparison between primary reconstruction and revision surgery was also performed with Wilcoxon rank sum and χ^2 tests. For the plain radiograph analysis, the independent t test was used. Clinical results of 3 different graft materials were compared with Kruskal-Wallis test. A P value of less than .05 was regarded as statistically significant.

Analysis of Failure

This study examined the failure observed in patients who underwent revision surgery in this institute. In some cases, there were combined problems, and each component was counted individually. With the numerous categories of

TABLE 2
Outcome Analysis of the Revision Surgery According to Graft Materials[a]

	IKDC				Lysholm				KT-2000 Arthrometer			
	Preoperative		Last F/U		Preoperative		Last F/U		Preoperative		Last F/U	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Hamstring	56.07	43-75	86.27	73-94	65.13	45-79	87.73	75-97	6.67	4-12	1.48	1-7
BPTB	63.20	43-74	87.95	75-93	69.70	49-77	89.25	78-96	7.38	5-11	1.50	2-6
Achilles	59.22	44-69	83.00	71-94	71.00	52-79	87.67	79-91	8.00	4-10	1.60	1-7
P	.064		.255		.082		.160		.321		.690	

[a]BPTB, bone–patellar tendon–bone; F/U, follow-up; IKDC, International Knee Documentation Committee.

failure, the population of failed ACL reconstruction is a diverse group and a hard subset to study. We analyzed the cause of failure by concentrating on recurrent patholaxity as follows: technical errors, failures due to biologic factors, failures due to catastrophic single-event trauma, and failures due to laxity in the secondary restraints.[4-6,17,22,23,27]

RESULTS

Clinical Results

For the primary reconstruction, the Lysholm score was 72.6 (range, 51-86) before surgery, and it improved to 93.7 (range, 71-99) after surgery. By the final evaluation on the criteria of IKDC, 75 cases (64.1%) were A (normal), 36 cases (30.8%) were B (nearly normal), 6 cases (5.1%) were C (abnormal), and there were no D cases (severely abnormal) (Figure 2). The difference between the scores before the surgery and at last follow-up evaluation was significant ($P < .001$).

For the revision surgery, the mean Lysholm score was 63.3 (range, 45-79) preoperatively and 84.6 (range, 75-97) postoperatively. The mean IKDC subjective score was 54.5 (range, 43-75) preoperatively and 84.5 (range, 71-94) postoperatively. The difference between the score before the revision reconstruction and at last follow-up evaluation was significant ($P < .001$). With use of the IKDC evaluation form at the last evaluation, 13 (23.2%) cases were rated as A (normal), 35 (62.5%) as B (nearly normal), 6 (10.7%) as C (abnormal), and 2 (3.6%) as D (severely abnormal) (Figure 2). The statistical comparison of the clinical results between primary reconstruction and revision surgery was significant ($P = .001$). There was no difference in clinical results (IKDC subjective score and Lysholm score) in different groups of graft material ($P = .255$ and .16, respectively) (Table 2).

Stability

For the primary reconstruction, maximal manual test result using KT-2000 arthrometer was a mean 8.5 mm (range, 3-20 mm) before surgery and was improved to a mean 1.3 mm (range, 1-6 mm) at final follow-up (Figure 3). In 109 cases (93.1%), the difference was less than 2 mm, in 3 cases it was from 3 to 5 mm, and in 5 cases it was more than 5 mm.

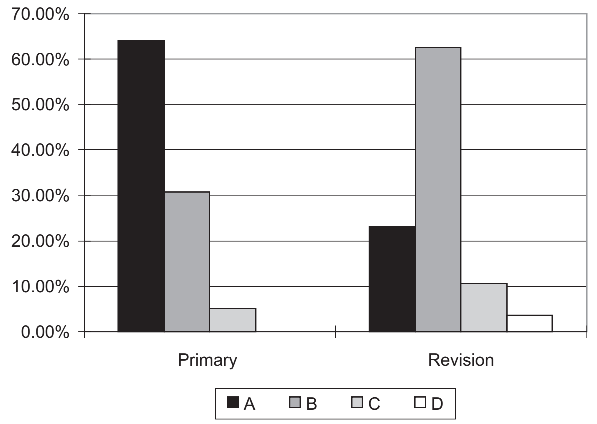

Figure 2. International Knee Documentation Committee objective score (clinical result) in the primary reconstruction and revision surgery.

For the revision surgery, the mean side-to-side difference as measured by the maximal manual test with the KT-2000 arthrometer was 8.7 mm (range, 3-12 mm) preoperatively and 1.5 mm (range, 1-7 mm) at the last follow-up evaluation (Figure 3). In 49 cases, the difference was less than 2 mm, in 5 cases it was from 3 to 5 mm, and in 2 cases it was more than 5 mm.

The difference between the value before the revision reconstruction and that at the last follow-up was significant ($P < .001$). On the Lachman testing, there were 9 cases with grade I, 26 with grade II, and 21 with grade III. At the last follow-up, 34 cases had normal Lachman test results, and 22 cases had a grade I laxity. The difference between the value before the revision reconstruction and that at the last follow-up was significant ($P < .001$). Preoperatively, 3 cases had grade I pivot-shift test results, 21 had grade II, and 20 had grade III. Postoperatively, 40 cases had negative pivot-shift results, and 16 had grade I results. The difference between the value before the revision reconstruction and that at the last follow-up was significant ($P < .001$). The statistical comparison of the stability results between primary reconstruction and revision surgery was not significant ($P = .338$). There was no

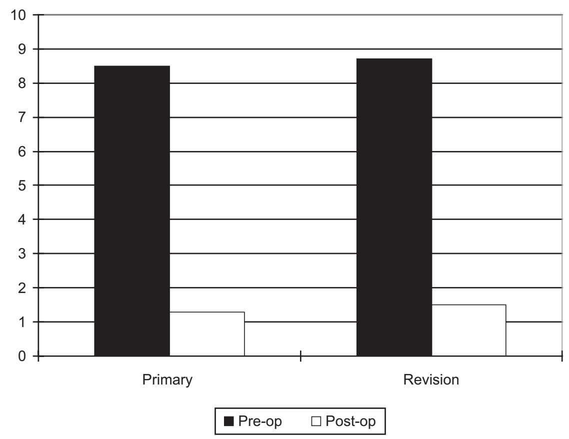

Figure 3. The KT-2000 arthrometer results (stability) in the primary reconstruction and revision surgery. Post-op, postoperative; Preop, preoperative.

difference in stability results (KT-2000 arthrometer) in different groups of graft material (P = .690) (Table 2).

Cause of Failure

The most common cause of failure was technical errors: malpositioned femoral and tibial tunnel (22 knees), too anterior femoral tunnel (9 knees), vertical femoral tunnel (10 knees), anterior and vertical (14 knees), too posterior tibial tunnel (7 knees), and too anterior tibial tunnel (4 knees). Trauma (10 knees), biologic factors (9 knees), and laxity due to the laxity in the secondary restraints (3 knees) followed. Thirty-five knees had multifactorial causes, and we counted each component individually.

Radiologic Results

Preoperatively, 21 cases had grade 0 Fairbank changes, 23 had grade 1, 9 had grade 2, and 3 had grade 3. Postoperatively, 18 patients had grade 0 Fairbank changes, 22 had grade 1, 11 had grade 2, and 4 had grade 3. The difference between the value before the revision reconstruction and that at the last follow-up was not significant (P = .74). In the comparison between the 2 subgroups (mild group, grades 0 and 1; severe group, grades 2, 3, and 4), the mild group's Lysholm and IKDC subjective scores were 90.38 (range, 83-97) and 87.14 (range, 78-94), respectively, and the severe group's Lysholm and IKDC subjective scores were 85.86 (range, 75-92) and 82.29 (range, 71-89), respectively. The difference was significant between 2 groups at the last follow-up as regards Lysholm and IKDC subjective scores, and the mild group showed better clinical results than did the severe group (P = .018 and .04, respectively).

DISCUSSION

Revision ACL reconstruction is likely to become more common as the number of primary reconstructions continues to increase each year because of the increasing numbers of people of all ages participating in athletic activities.[5] Revision surgery is considered to be more technically demanding than is primary ACL reconstruction, and some authors state that postoperative results are less than optimal with regard to stability, return to sports, and overall patient satisfaction.[22,27,34] In the present study, the clinical results were inferior to those from our primary reconstruction, but as regards stability, the difference between primary and revision cases was not significant.[1,3] The results of revision ACL reconstruction are generally inferior to those of primary reconstruction.[16,20,22,24,26,30,31,33] However, with respect to the inferior results of revision ACL reconstruction, it is unclear whether this is owing to inferior knee stability or to other clinical results. Thomas et al[30] prospectively compared clinical results of 49 two-stage revision ACL with 49 primary reconstructions. They used 2 different autografts (15 BPTB and 34 double-looped semitendinosus and gracilis autograft) and reported no significant differences in the stability and inferior subjective and functional outcome for the revision surgery.[30] This is in line with the present study. Weiler et al[32] evaluated the primary and revision ACL reconstruction with comparative matched-group analysis with just 1 type of graft. They reported equivalent results in terms of IKDC score and objective knee stability between primary reconstruction and revision surgery.[13] Our results are similar to those reported by Weiler et al[32] in terms of stability, but IKDC score of the revision surgery was inferior to that of the primary reconstruction group.

Many factors may be involved in the failure of an ACL reconstruction, including the surgical technique, the selection of graft material, the integrity of the secondary restraints, the condition of the articular cartilage and menisci, postoperative rehabilitation, and the motivation and expectations of the patients.[19] However, the cause of failure of an ACL reconstruction may be difficult to determine, and more than 1 cause may be responsible for failure.[17,19,34] There is no universally accepted definition as to what qualifies as an unsatisfactory outcome after ACL surgery.[4] We focused on recurrent patholaxity and considered each component individually in patients who had more than 1 cause. Generally, it is said that the most avoidable and the most common cause of failure is surgical technique.[22,27,34] The most common cause of failure in our study was technical errors, especially femoral tunnel position. Technical error constituted 75% of the failures (66 of 88 causes).

As for the graft material, 21 (37.5%) double-looped semitendinosus and gracilis autografts, 20 (35.7%) BPTB allografts, and 15 (26.8%) Achilles allografts were used in the present series. No significant functional or objective differences have been found between revision ACL reconstruction with autografts and those with allografts, although this has been debated recently.[5,9-11,13,22] We did not find any statistically significant difference between different graft materials in our series. Double-looped hamstring tendon autografts have been shown to have an ultimate load to failure of 250% (4108 N) of that of the normal ACL.[21] From these data, one expects the double-looped hamstring tendon to be strong enough for revision ACL reconstruction. However, there are disadvantages to this approach, including the additional graft harvesting effort and time and relatively short length of the prepared tendon. However, graft length is not problematic in ACL reconstruction because enough length for ACL reconstruction can be acquired, and extending the graft with Mersilene tape or using a double fixation technique with a post tie screw and washer can be used if the graft is short.[2] However, no patient in this series required Mersilene tape to extend the graft.

Progression of osteoarthritis in knees with chronically insufficient ACL has been reported previously.[10] This is the reason it is recommended to restore stability before further injuries occur that could lead to degenerative changes. Even after successful stabilization, however, progressive osteoarthritis has been reported in knees with partial or especially complete meniscus resection.[10-12] In the present study, we could not find statistical difference as regards degenerative change between the value before the revision reconstruction and that at the last follow-up. However, there cannot be any definite conclusion about the degenerative change because the follow-up period of this study was relatively short. We divided patients into 2 subgroups (mild group, grades 0 and 1; severe group, grades 2, 3, and 4) according to the Fairbank scale. The Lysholm and IKDC subjective scores in 2 groups at the follow-up were significantly different; the mild group showed better clinical results than did the severe group. Our results showed that the results were better in no or mildly degenerated group.

In conclusion, despite the limitations of this retrospective study (small series, relatively heterogeneous materials, and too many variables), the results suggest that (1) revision ACL reconstruction can improve clinical and stability results, but the clinical results are inferior to those of primary ACL reconstruction. (2) The clinical outcomes for the double-looped hamstring tendon autograft group are as good as those for Achilles allograft or BPTB allograft group. This might imply that the success of the operation does not depend on the choice of graft materials. (3) The clinical results were better in the no or mildly degenerated group.

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