Occurrence Rate of Cyclops Lesion After Anatomic Double-Bundle ACL Reconstruction

Comparison Between Remnant Tissue Preservation and Resection Methods

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Background: The occurrence rate of cyclops lesion after anatomic double-bundle anterior cruciate ligament (ACL) reconstruction with remnant tissue preservation remains unclear.

Hypothesis: The study hypotheses were as follows: (1) the occurrence rate of cyclops lesion will be comparable between the remnant-preserving and remnant-resecting ACL reconstruction methods, and (2) there will be no significant differences in clinical outcomes between the remnant-preserving and remnant-resecting procedures.

Methods: This retrospective comparative study involved 177 patients who underwent unilateral anatomic double-bundle ACL reconstruction using hamstring tendon autografts from 2014 to 2018 at our hospital. According to the Crain classification of ACL remnant tissue, 98 patients with remnant types I, II, or III underwent the remnant-preserving procedure (group A), and the remaining 79 patients with remnant type IV underwent the remnant-resecting procedure (group B). All patients underwent second-look arthroscopy. Patients were evaluated according to arthroscopic and clinical results at postoperative 15.2 ± 8.4 months (mean ± SD). Statistical comparisons between groups were made using the paired Student t test, chi-square test, and Fisher exact test.

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

Results: At second-look arthroscopy, the incidence of cyclops lesions was significantly higher in group B than in group A (29.1% vs 13.3%; P = .0139). Cyclops lesions were divided into 4 locations: femoral side (type 1), midsubstance (type 2), tibial side (type 3), and anterior (type 4) of the ACL graft. The ratio of the tibial-side cyclops lesion (type 3) was significantly higher in group B than in group A (P = .0354). There were no significant differences in the clinical evaluation scores between the procedures. Side-to-side anterior laxity was significantly less in group A than in group B (0.7 vs 1.6 mm; P = .0035). Concerning postoperative laceration and synovium coverage of the grafts, group A was significantly better than group B (P < .0001).

Conclusion: In this cohort of patients undergoing double-bundle ACL reconstruction, resection of the ACL remnant was associated with a significantly higher rate of cyclops lesion formation when compared with preservation of the remnant.

Keywords: cyclops lesion; second-look arthroscopy; double-bundle ACL reconstruction; remnant tissue preservation

Cyclops syndrome and lesions were first described by Jackson and Schaefer in 1990.16 They found that a group of patients with the inability to regain full extension had characteristic arthroscopic findings, including a fibrous nodule with central granulation tissue anterolateral to the tibial tunnel. This proliferative process in the intercondylar notch after anterior cruciate ligament (ACL) reconstruction has been termed cyclops syndrome (symptomatic cyclops lesion).27 The incidence of cyclops syndrome has been reported to be between 1% and 10% of all ACL
reconstructions, whereas magnetic resonance imaging studies have found an incidence of 25% to 47% for cyclops lesions. These lesions are characterized by the development of fibrovascular tissue anterior to the ACL graft. Cyclops lesions have been noted to be more common in double-bundle and quadriceps graft ACL reconstruction than in single-bundle and hamstring graft ACL reconstruction. The incidence in double-bundle ACL reconstruction is 3.6%, and the cause is thought to be a higher volume of the graft that impinges on the posterior cruciate ligament (PCL) synovium posteriorly, with the lesion arising from the synovium of the PCL rather than the graft.

Preservation of the ACL remnant has remained a topic of interest. Remnant preservation has been expected to have several potential advantages to improve postoperative knee stability, such as enhanced graft coverage with fibrous tissues, accelerated cell repopulation and revascularization, maintenance of the native broad tibial enthesis, and reduction of bone tunnel enlargement, although these points are debatable. However, there has been some apprehension that remnant preservation may increase the occurrence rate of cyclops syndrome or cyclops lesion after ACL reconstruction surgery. Only a few studies have shown no significant association in single-bundle ACL reconstruction between remnant preservation and the presence of a cyclops lesion.

We recently developed anatomic double-bundle ACL reconstruction with ligament remnant tissue preservation, and it has significantly improved postoperative knee stability. Several investigators reported increased symptomatic cyclops lesion with double-bundle ACL reconstruction with remnant tissue preservation. Yet, Tanabe et al found no difference in the incidence of cyclops lesions between remnant-preserving and remnant-resecting ACL reconstructions. Therefore, the occurrence rate of cyclops lesion after double-bundle ACL reconstruction with remnant tissue preservation remains unclear.

In the current study, we compared the occurrence rate of cyclops lesion between the remnant-preserving and remnant-resecting procedures after anatomic double-bundle reconstruction. We proposed the following 2 hypotheses: (1) The occurrence rate of cyclops lesion may be comparable between anatomic double-bundle reconstructions that preserve the remnant tissue and those that resect the remnant tissue. (2) There would be no significant differences in clinical outcomes after anatomic double-bundle ACL reconstruction between the remnant-preserving and remnant-resecting procedures based on remnant type.

METHODS

Study Design

A retrospective comparative study involved patients who underwent unilateral double-bundle ACL reconstruction from January 2014 to May 2018 in our hospital. Exclusion criteria involved patients with an isolated anteromedial (AM) or posterolateral (PL) bundle tear, patients with a combined injury in the other knee ligaments, and patients who had undergone any previous knee surgical treatments. Informed consent for the use of medical information was obtained from all patients at the time of follow-up in the present study. The protocol of the present study was approved by the institutional review board of our institution.

Figure 1. Study design and follow-up examinations. ACL, anterior cruciate ligament; ACLR, ACL reconstruction.
A total of 209 consecutive patients (209 knees) were enrolled (Figure 1). At the time of ACL reconstruction, we arthroscopically observed the morphological status of the remnant tissue in each participant and divided the patients into the 2 groups as follows. For the purposes of the present study, the knees having remnant tissue classified as Crain type I, II, or III, the proximal end of which attached on the femur or the PCL, were categorized as group A. The knees with Crain type IV remnant tissue, the proximal end of which did not attach anywhere although the distal end attached on the tibia, were categorized as group B. Because type IV remnant tissue was obviously different from the other types, knees in groups A and B were able to be distinguished with high reproducibility.

Of the 209 patients, 111 patients in group A (Crain type I-III remnant tissue) underwent arthroscopic anatomic double-bundle ACL reconstruction with preservation of the remnant tissue. The other 98 patients in group B (Crain type IV remnant tissue) underwent arthroscopic anatomic double-bundle ACL reconstruction after resection of the remnant tissue.

Two senior orthopaedic surgeons (E.K. and K.Y.) who were sufficiently trained concerning the 2 procedures performed all operations. We followed up with the patients in our outpatient clinic for ≥2 years after surgery; 13 and 19 patients were lost during follow-up in groups A and B, respectively. Thus, a total of 177 patients participated in the present study and underwent second-look arthroscopy at approximately 1 to 2 years after surgery, when 2 staples inserted into the tibia were removed (Figure 1).

Preoperative Laxity Measurement

Side-to-side anterior laxity was measured using a Knee-Lax3 joint arthrometer (Monitored Rehab Systems) at 30° of knee flexion under an anterior drawer force of 133 N. All measurements were performed by an independent experienced physical therapist who was blinded to the study procedure.

Operative Procedure

Anatomic Double-Bundle Reconstruction With Remnant Tissue Preservation. The remnant-preserving anatomic double-bundle reconstruction procedure was performed for the group A patients according to a previous study. Briefly, we inserted a guide wire for the tibial PL tunnel using a hole-in-1 guide (Wire-Navigator; Smith & Nephew) that was developed for the transtibial tunnel technique. After we confirmed the guide wire position using a C-arm fluoroscope, a 5-mm offset guide (Transtibial AM Tunnel; Arthrex) was placed on the posterior part of the lateral condyle at the 1:30 or 10:30 clockface position through the previously described small slit. After a guide wire was inserted, we gently drilled a femoral AM tunnel via a tibial AM tunnel without detaching the adherent attachment of the remnant from the PCL or the femur. Then, the surgeon manually inserted a guide wire into the joint cavity through the tibial PL tunnel and the remnant tissue and aimed it at the center of the femoral attachment of the PL bundle midsubstance. We determined an appropriate guide wire location using the previously reported fluoroscopic method. After the guide wire was inserted, a femoral PL tunnel was gently reamed via a PL tunnel by use of a cannulated drill, penetrating the remnant tissue.

For graft preparation, the harvested semitendinosus tendon was cut to half its length and doubled over. The minimum length was 110 mm. The lengths of the autografts were 60 to 70 and 50 to 60 mm for the AM and PL bundle grafts, respectively. A commercially available polyester tape (Leeds-Keio Artificial Ligament; Neoligaments) was mechanically connected at an unlooped end of the doubled tendon by use of a previously reported technique. An EndoButton CL-BTB (Smith & Nephew) was attached at the looped end. The size of the EndoButton CL was adjusted so that an autogenous tendon portion of 15 to 20 mm was located in the femoral and tibial tunnels. Each graft was introduced through each tibial tunnel, and the remnant tissue into the femoral tunnel, and fixed with an EndoButton. The 2 tape portions were simultaneously secured with 2 spiked staples (Smith & Nephew) onto the tibia at 10° of knee flexion, with a 30-N load applied to each graft.

Anatomic Double-Bundle Reconstruction Without Remnant Tissue Preservation. Surgery was performed with the original procedure reported in 2004. The ACL remnant tissue in group B patients was resected before the tibial tunnels were created. The same 2 tendon grafts were prepared and placed into each pair of tunnels. The 2 grafts were simultaneously secured onto the tibia in the same manner as the remnant-preserving procedure.

Second-Look Arthroscopy

Occurrence of Cyclops Lesions. The primary outcome measure was the occurrence rate of cyclops lesions on second-look arthroscopy. The presence and appearance of cyclops lesions were assessed by a senior surgeon with 25 years of experience in arthroscopic knee surgery (E.K.). As published previously, we defined cyclops lesion as a pedunculated or nonpedunculated nodule of fibrovascular tissue around the ACL graft whose size was >5 mm in long diameter. We defined cyclops syndrome as the presence of cyclops lesions and concomitant loss of ≥5° of knee extension. Patients with clinical symptomatology without nodulation or fibrosis in the region anterior to the ACL were not considered to have cyclops syndrome.
When a cyclops lesion was detected, it was classified according to location and morphology. Most of the lesions could be classified into 1 of 3 types by location according to Kambhampati et al\textsuperscript{19}: at the femoral side of the ACL graft (type 1), the midsubstance of the ACL graft (type 2), or the tibial side of the ACL graft (type 3) (Figure 2, A-C). We occasionally detected the extended fibrous tissue, which was located anterior to the ACL graft under arthroscopic appearance (Figure 2D). We also found that this tissue changed its shape among the different knee positions. In the knee extension position, it appeared to have a warped shape (yellow arrowhead) on preoperative sagittal T2-weighted magnetic resonance imaging (Figure 2E). However, in the knee flexion position, it appeared to be tightened up like an accordion curtain in the arthroscopic appearance (Figure 2D). We named this new pattern an “accordion type” cyclops lesion (type 4).

**Overall Graft Quality.** The reconstructed ACL graft was carefully observed in the leg-hanging and figure-of-4 positions, using a probing technique. In almost all patients, the 2 grafts were enveloped by a relatively thick fibrous tissue, the surface of which was covered by a thin synovial membrane, so that it was difficult to separately observe the 2 bundles. We therefore evaluated the quality of the overall reconstructed ACL based on graft laceration or tear and synovial and fibrous tissue coverage of the grafts, using the following guidelines modified from previous studies.\textsuperscript{21,23}

![Figure 2. The locational and morphologic variants of cyclops lesions. (A) Type 1 was found at the femoral side of the ACL graft, (B) type 2 at the midsubstance of the ACL graft, (C) type 3 at the tibial side of the ACL graft, and (D) type 4 (accordion type) anterior to the ACL graft. (E) In the knee extension position on preoperative sagittal T2-weighted magnetic resonance imaging, it appeared as a warped shape (yellow arrowhead). ACL, anterior cruciate ligament.](image)

![Figure 3. Second-look arthroscopic examination. (A-C) The laceration or tear of the grafts was graded as follows: no laceration or elongation of a sufficiently thick graft (grade A); partial laceration of a sufficiently thick graft or no laceration or elongation of a relatively thin graft (grade B); or complete tear or obvious elongation of a graft (grade C). (D-F) The synovial and fibrous tissue coverage of the grafts was graded as follows: completely covered with the synovial tissues (grade A); partially covered (grade B); or almost not covered (grade C).](image)
The laceration or tear of the grafts was graded as follows: no laceration or elongation of a sufficiently thick graft (grade A; 2 points); partial laceration of a sufficiently thick graft or no laceration or elongation of a relatively thin graft (grade B; 1 point); or complete tear or obvious elongation of a graft (grade C; 0 points) (Figure 3, A-C). In addition, the synovial and fibrous tissue coverage of the grafts was graded as follows: completely covered with the synovial tissues (grade A; 2 points); partially covered (grade B; 1 point); or almost not covered (grade C; 0 points) (Figure 3, D-F). For the overall evaluation, the 2 scores were then summed, and bundles were evaluated as excellent (4 points overall), fair (2 or 3 points overall), or poor (0 or 1 point overall).

**Clinical Evaluation**

Each patient underwent clinical examination a few days before undergoing second-look arthroscopy. Clinical outcome measures included the Lysholm knee score (maximum score, 100) and the International Knee Documentation Committee (IKDC) examination form. Iso-kinetic peak torque of the quadriceps and hamstring tendons was measured at 60 deg/s of angular velocity using a Cybex II dynamometer (Lumex) in both knees before undergoing second-look arthroscopy. Peak torque, as measured postoperatively in the reconstructed knee, was represented as a ratio (percentage) of the injured to uninjured knee. Postoperative side-to-side anterior laxity was measured in the same manner as preoperatively. In addition, the pivot-shift test was performed by 2 well-trained orthopaedic surgeons (R.H., E.K.). A positive result was defined as when the examiner felt some difference in the rotational movement during the test between the injured and uninjured knees but did not obviously feel a sudden rotational slip movement. This result indicated some insufficiency of ACL function but did not indicate complete failure of the ACL. A result of 2+ was defined as when the examiner felt a sudden rotational slip movement between the tibia and femur, a so-called jog, during the test for the injured knee.

### TABLE 1

Demographic and Clinical Characteristics of the Study Groups

| Variable                          | Group A (n = 98) | Group B (n = 79) | P Value |
|-----------------------------------|-----------------|-----------------|---------|
| Sex, male/female, No.             | 59:39           | 45:34           | .7581   |
| Age, y                            | 29.2 ± 12.8     | 28.4 ± 13.4     | .8013   |
| Height, cm                        | 166.1 ± 8.7     | 165.1 ± 8.7     | .4495   |
| Body weight, kg                   | 65.8 ± 13.6     | 63.8 ± 12.4     | .3022   |
| Preoperative side-to-side anterior laxity, mm | 5.2 ± 2.1 | 5.9 ± 2.1 | .1698 |
| Time from injury to surgery, mo   | 6.0 ± 15.9      | 9.7 ± 16.8      | .1452   |

*a Data are reported as mean ± SD unless otherwise indicated.

*b Group A: patients who underwent remnant-preserving procedure: Crain type I-III remnant tissue.

*c Group B: patients who underwent remnant-resecting procedure: Crain type IV remnant tissue.

### TABLE 2

Occurrence of Cyclops Lesion and Cyclops Syndrome by Location on Second-Look Arthroscopy

|                  | Group A (n = 98) | Group B (n = 79) | P Value |
|------------------|-----------------|-----------------|---------|
| Cyclops lesions   |                 |                 |         |
| Type 1           | 13 (13.3)       | 23 (29.1)       | .0139   |
| Type 2           | 5 (5.1)         | 2 (2.5)         | .0733   |
| Type 3           | 4 (4.1)         | 3 (3.8)         | .2254   |
| Type 4           | 3 (3.1)         | 15 (19.0)       | .0354   |
| Cyclops syndrome |                 |                 |         |
| Type 1           | 4 (4.1)         | 3 (3.8)         | .9231   |
| Type 2           | 2 (2.0)         | 0 (0)           | .1227   |
| Type 3           | 1 (1.0)         | 0 (0)           | .2759   |
| Type 4           | 0 (0)           | 0 (0)           | —       |

*a Data are reported as No. (%) of patients.

*b Bold P values indicate statistically significant differences between groups (P < .05). Dash indicates not available.

*c Classified according to location relative to the graft: femoral side (type 1), midsubstance (type 2), or tibial side (type 3). Type 4 (accordion-type lesions) were located anterior to the anterior cruciate ligament graft.

The 2+ pivot-shift result indicated an obvious failure of ACL function.

**Statistical Analysis**

Data are presented as means and standard deviations or counts and percentages. The Student t test and the chi-square test were used to assess the demographic parameter, clinical, and second-look arthroscopic differences between the groups. The Fisher exact test was used to assess the occurrence rate of the cyclops lesions. Commercially available software programs, JMP Pro Version 13.1 and SAS Version 9.4 (SAS Institute) were used for statistical calculations. The significance level was set at P = .05.

**RESULTS**

**Patient Demographics**

The 177 patients consisted of 104 men and 73 women with a mean age of 29 years (range, 13-66 years) at the time of surgery. There were 98 patients in group A and 79 patients in group B. The mean time from injury to ACL reconstruction was 6.0 months in group A and 9.7 months in group B. The other background factors in each group are shown in Table 1. There were no significant differences between the groups on any variable, including preoperative anterior laxity. The mean period from ACL reconstruction to second-look arthroscopic examination was 15.2 ± 8.4 months (range, 8-96 months).

**Second-Look Arthroscopy**

On second-look arthroscopy, the occurrence rate of the cyclops lesion was significantly less in group A than in
The most important finding of the present study was that the occurrence rate of cyclops lesion of the remnant-removing double-bundle ACL reconstruction procedure (mean, 29.1\% for patients with Crain type IV remnant tissue) was significantly higher than that of the remnant-preserving procedure (13.3\%) for patients with...
Crain type I, II, or III remnant tissue (group A). There was a significant difference in the locational patterns of the cyclops lesion between the groups. Regarding the occurrence rate of cyclops syndrome, there was no significant difference between the groups (4.1% and 3.8% in groups A and B, respectively). Additionally, although there were no significant differences in the clinical evaluations between the groups, knee stability was significantly better in group A than in group B.

Regarding the double-bundle remnant preservation procedure, Muneta et al. reported an increased extension deficit for knees preserving a large remnant. Nakayama et al. found that hyperproliferation of the synovia (ie, cyclops syndrome) was identified in 9 of 13 cases in the preservation group, while this was not observed in the nonpreservation group. Yet, Kondo et al. stated that a cyclops lesion without any clinical symptoms was observed in 14.5% of the remnant-preserving procedure and in 17.4% of the remnant-resecting procedure. There were no significant differences in the occurrence rate of cyclops lesions between the procedures. In the present study, the occurrence rate of the cyclops lesion was significantly higher in group B than in group A. This result may be caused by a few features that were different from the previous studies. First, we did not perform single-bundle reconstruction but rather double-bundle reconstruction. There is a possibility that the effect of remnant preservation may be detected differently between the single- and double-bundle procedures. Second, the procedure used in the present study was beneficial to sufficiently cover the tendon grafts with the remnant tissue, as compared with the previous procedures. Namely, the proximal attachment of the ACL remnant was not detached from the femur or PCL in this procedure, whereas it was detached in the previous procedures.

Mueellner et al. noted that symptomatic cyclops lesions were hard in consistency and, on microscopy, revealed fibrocartilaginous tissue with active bone formation in the center. However, asymptomatic lesions were soft and had only fibrocartilaginous islands surrounded by granulation tissue on microscopy. The incidence of all types of cyclops progressively increases with time: one study reported that the incidence increased from 25% at 6 months after ACL reconstruction to 33% by the end of 1 to 2 years, whereas another noted a 46.8% incidence by 1 year of which only 10.6% of the cases were symptomatic. In the present study, the second-look arthroscopic examination was performed at 15 months after primary ACL reconstruction (range, 8-96 months).

The most common site of the cyclops lesion is the anterolateral aspect of the tibial insertion site of the ACL graft. The inverted cyclops lesion may have a stalk leading to the femoral tunnel, or it may occur without any connection to the femoral tunnel. In the present study, the tibial side of the cyclops lesion occurred with greater frequency in group B. These results suggest that the cyclops lesion frequently occurred from the resected tibial remnant tissue. Yet, the femoral side of the cyclops lesion had a tendency to be detected in the remnant-preserving procedure. Several reasons are considered for this, such as graft impingement and graft coverage with the remnant tissue. In addition, the accordion-type cyclops lesion (type 4 in the current study) was occasionally detected anterior to the ACL graft. It is well known that the ligamentum mucosum (the infrapatellar plica) is an embryological remnant of a synovial septum. In ACL reconstruction, surgeons usually resect the ligamentum mucosum. Therefore, the thick fibrous band between the femoral notch and fat pad may recur after arthroscopic surgery. However, despite differences between the study groups in the distribution of cyclops lesions and objective laxity, there was no difference between the groups in terms of other outcomes. Thus, it is hard to determine the clinical relevance of the finding of an “asymptomatic” cyclops lesion in this 2-year clinical outcome. Therefore, studies are needed of long-term outcomes after double-bundle ACL reconstruction with remnant tissue preservation.

According to the overall arthroscopic evaluation guideline, the remnant-preserving group had significantly better results than the remnant-resection group. The arthroscopic evaluations performed in a previous study showed that a strong relationship existed between the appearance of the 2 bundles and (1) the postoperative anterior laxity and (2) the pivot-shift test result. The present study also showed that preservation of the ACL remnant tissue is effective in improving knee stability after anatomic double-bundle ACL reconstruction. In addition, the knees in group A had a significantly higher percentage of negative pivot-shift test results, 90% as compared with 77%.

Crain et al. reported that resection of remnant types I to III resulted in increased intraoperative laxity (prior to reconstruction). In contrast, there was no significant increase in laxity after debridement of a type IV remnant. Based on the findings of Crain et al, the initial pathology may be just as important as the treatment in producing our findings. In the present study, the significantly better postoperative knee stability in group A did not result in significantly better results on functional and objective clinical evaluations, although there were no significant differences in the preoperative knee laxity between the groups.

We speculated about the reasons why postoperative knee stability was significantly improved by preservation of the ACL remnant tissue in the present study. Previous studies noted that revascularization in the graft is not evident in remnant-resected ACL reconstruction. The ACL remnant tissue has good subsynovial and intrafascicular vascularity. Wu et al. recently reported in an experimental study that blood flow in the graft was significantly higher in the remnant-preserved group than in the remnant-resected group. Therefore, first, remnant preservation in ACL reconstruction may accelerate cell repopulation and revascularization in the graft, resulting in acceleration of graft remodeling. Second, the present study showed that in remnant-preserved reconstruction, the graft appearance in second-look arthroscopy was significantly better in the remnant-preserving procedure than in the remnant-resection group. We recently examined the efficacy of remnant tissue preservation for graft healing in ACL reconstruction using a sheep model. Preservation of the remnant tissue in ACL reconstruction enhanced cell
proliferation, revascularization, and regeneration of proprioceptive organs in the reconstructed ACL and reduced the anterior translation. These results imply that preservation of the ACL remnant tissue may improve graft healing after ACL reconstruction.

Several authors found no significant differences regarding postoperative Lysholm, IKDC, and/or Tegner scores between the remnant-preserving and remnant-resecting double-bundle ACL reconstruction methods. Systematic reviews stated that there was no significant difference in objective, subjective, or functional clinical outcome. A meta-analysis recently reported that the Lysholm scores and IKDC subjective scores showed statistically minor differences but no significant difference in subgroup analysis. Thus, its actual clinical effectiveness is still controversial.

Limitations

There are some limitations in the present study. First, there was bias in our indications to preserve or resect remnant tissue: We preserved remnants in configurations that were likely to be contributing to stability and resected remnants previously found to have no influence on subsequent laxity. As an example of observations that may have been influenced by preservation of remnant tissue, the laxity differences in remnant types I to III were noted by Crain et al. to have an effect in limiting anterior knee displacement. The second limitation is that the follow-up period was 2 years. Therefore, we cannot speculate whether there will be differences between the procedures in long-term outcomes in knee function. The third limitation is that we did not compare proprioceptive sensation between the groups because we had no specific facilities for such evaluation. It has become difficult to clinically measure proprioceptive sensation because such devices are not commercially available in the clinical field.

CONCLUSION

In this cohort of patients undergoing double-bundle ACL reconstruction, resection of the ACL remnant was associated with a significantly higher rate of cyclops lesion formation as compared with preservation of the remnant.

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