INTRODUCTION
Failed treatment for avulsion fracture of the tibial attachment of the anterior cruciate ligament (ACL) leads to anterior knee instability when the avulsion fragment is displaced. Anatomical reduction and fixation of the fragment are widely recommended for type III and IV displaced fracture. Although several surgical techniques for arthroscopic reduction and internal fixation (ARIF) of the avulsion fragment have been developed, the outcome in adult patients varies and prolonged postoperative immobilization has been raised as a risk factor of loss of knee motion (1). Since the period of postoperative immobilization greatly depends on the initial fixation strength at the fixation site, the rigid fixation of the avulsion fragment of the ACL attachment is the key to minimize the motion complications. However, it remains unclear which fixation technique is most effective to obtain initial fixation strength. Therefore, the objective of this study was to compare the initial fixation strength in response to a cyclic load between three different fixation techniques for ACL avulsion fractures: 1) antegrade screw fixation, 2) retrograde screw fixation, and 3) pull out suture fixation.

MATERIALS AND METHODS
Fifteen fresh-frozen human amputated knees from patients with an average age of 58.6 were used for this study. Informed consent was obtained from the patients and ethical approval of this study was obtained from the Ethics Committee of Hiroaki University School of Medicine. Specimens were divided into three groups of five knees each based on fixation techniques. The specimen was mounted on a materials testing machine (Instron 4465; Instron Corp., Canton, Massachusetts, USA) with 30 degrees of knee flexion and neutral internal-external and varus-valgus rotation restricting the other three degrees of freedom (anterior-posterior, medial-lateral and proximal-distal translation). Neutral anterior-posterior position of intact knee was defined as the position midway between the two zero load points of the load-displacement hysterisis loop by imposing ±50N drawer cycle. On the testing machine, the tibial eminence including the whole area of the ACL tibial attachment was completely isolated from the tibial plateau with an osteotome to produce a type III fracture (Fig. 1A). After the anatomical reduction, the avulsion fragment was fixed with the titanium cannulated cancellous screw (4.0 mm of diameter) with spiked washer (Depuy ACE, Warsaw, Indiana, USA) inserted from the center of the avulsion fragment to the posterolateral cortex (Fig. 1B) in the antegrade screw fixation (ASF) group. In the retrograde screw fixation (RSF) group, the titanium screw described above was inserted from the anteromedial cortex to the center of the avulsion fragment so that the tip of the screw protruded to the joint surface slightly (Fig. 1C). In the pull-out suture fixation (PSF) group, the fragment was secured with doubled No.2 Ethibond suture (Ethicon, Inc., Somerville, New Jersey, USA) pulled-out through the bone holes, and tied on the anteromedial tibial cortex (Fig. 1D). The repaired knee was subjected to 500 cycles of 0 to 100-N cyclic anterior tibial loads at a crosshead speed of 100 mm/min. The anterior tibial translation (ATT) in response to an anterior load of 100-N before and after 500 cycles of the loading was determined in reference to the neutral A-P position defined in the intact knee. To quantify the loss of graft fixation, the parameter "laxity increase" introduced by Scheffler et al (2) was determined as the change in the tibial position at load pickup between the first cycle and the last cycle of cyclic loading. The statistical analyses were performed using Scheffe test to compare the ATT and the laxity increase between repair techniques. The level of significance was set at p<0.05.

RESULTS
The increase in the ATT between before and after 500 cycles of the loading in PSF (2.2 ± 0.8 mm) was significantly larger compared with that in ASF (1.0 ± 0.2 mm). The ATT in RSF increased by 2.0 ± 0.6 mm after the cyclic loading, which tended to be larger than ASF. No significant differences in the laxity increase were detected between the three groups, however, the laxity increase in PSF (1.8 ± 1.0 mm) and RSF (1.7 ± 0.6 mm) tended to be larger than that in ASF (0.9 ± 0.2 mm) (Fig. 2).

DISCUSSION
The results of this study demonstrated that the ASF was the most effective technique to obtain initial rigid fixation. These results support the successful clinical outcome of ASF reported by Senekovic et al (3). Since the tip of the screw must penetrate into the fragment to obtain rigid fixation in RSF, the use of this fixation technique might be limited when the fragment is thin or comminuted. The largest laxity in PSF seems to be caused by tightening at the suture knot and the suture cutting into the tibial bone bridge. In conclusion, the results of this study suggested that the ASF was a suitable fixation technique for ACL avulsion fracture to obtain initial rigid fixation and allow early postoperative mobilization. In contrast, greater care is necessary during postoperative mobilization after PSF.

REFERENCES
1) Montgomery KD: Arthroscopy 18: 171-176, 2002
2) Scheffler SU: Arthroscopy 18: 304-315, 2002
3) Senekovic V: Arthroscopy 19: 54-61, 2003

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