자가 이식건을 이용한 사체 후방십자인대 재건술 후 이식건의 최대인장강도 거동

Ultimate Tensile Strength Behavior After Cadaveric Posterior Cruciate Ligament Reconstruction Using Autograft

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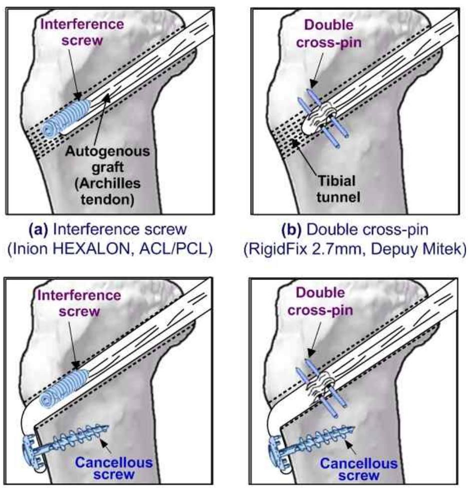
1. Introduction

The most important engineering approach among these diverse techniques is to understand and evaluate the fatigue behaviour precisely according to stress flow and stress redistribution under cyclic loading, and the size of each loading on graft, fixation device, and proximal tibia under PCL reconstruction using graft. As the fundamental research of the above-mentioned in this study, transtibial tunnel surgery with cadaveric Achilles tendon is adopted from among diverse empirical PCL reconstruction techniques, and initial lengthening behaviour of Achilles tendon according to fixation device or fixation location of the tendon under cyclic loading is studied. It also explained the slippage behaviors according to fixation method of calcaneus and fixation method of soft tissues of Achilles tendon, and the relationship between the lengthening ratio and the slippage ratio. It is the first study done on transtibial tunnel surgery with Achilles tendon in PCL reconstruction, and it is expected for many of new results that are the marriage of clinical results and diverse engineering approaches to be reported in the future. It is expected that this study will be the fundamental research materials that will contribute to the practical surgical techniques for future PCL reconstruction.

Table 1 Proximal Tibia list by four male's fresh frozen cadaver

Regist.	No.	Notice of death	Year	Gender	Disease entity
07-26	1*	2007.05.12	56.3	male	brain edema
	2**				
07-11	3**	2007.01.30	69.8	male	gastric cancer
	4*				
07-29	5*	2007.06.02	40.9	male	hepatoma
	6**				
07-10	7**#	2007.01.29	30.3	male	intracranial hemarrhage
	8*#				

* transtibial one-tunnel *with interference screw fixation*
** transtibial one-tunnel *with double cross-pin fixation*
*# transtibial one-tunnel *with interference screw fixation and cancellous screw*
**# transtibial one-tunnel *with double cross-pin and cancellous screw*

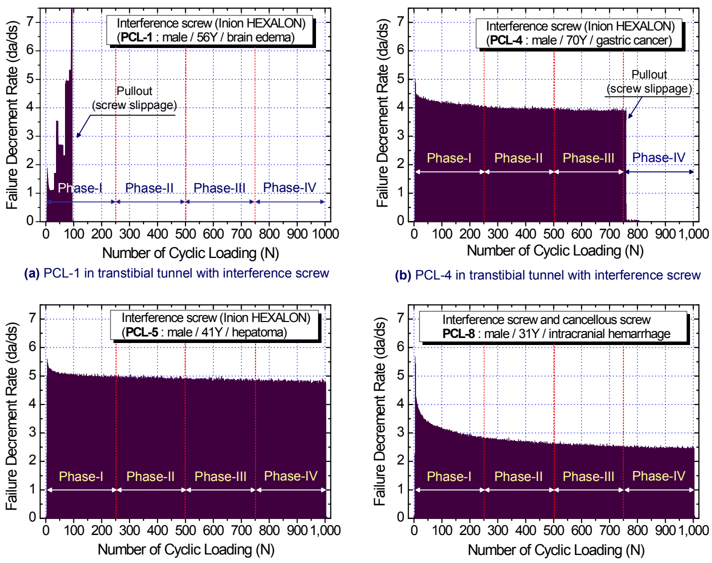


(a) Interference screw (Inion HEXALON, ACL/PCL)
(b) Double cross-pin (RigidFix 2.7mm, Depuy Mitek)
(c) Interference screw *with cancellous screw*
(d) Double cross-pin *with cancellous screw*

Fig. 1 Schematic drawing of four different fixation device in the transtibial one-tunnel

2. Fabrication of the Transtibial Tunnel Specimen

The transtibial tunnel method executed in this study for PCL reconstruction has a demerit called "killer turn", which is a condition of either a severance or a lengthening of the Achilles tendon caused by the drastic angle change of graft at the PCL attachment. Although a tibial inlay method is accompanied recently, an additional incision or a positional change of the patient in operation is required; therefore, the transtibial tunnel method is still the widely-used operation technique in PCL reconstruction. The tibia specimens were collected from four fresh frozen cadavers. To make the transtibial tunnel, incise from the lateral decubitus to the semimembranosus tendon of the popliteal fossa, detach the central portion of the gastrocnemius muscle of mediolateral side, and incise the capsular perpendicularly after removing the nerves and vessels of the popliteal fossa. Afterwards, incise the tibia at 200 mm distal to the tibia on tibial plateau and collect 8 specimens of the proximal tibia. The Achilles tendons(d=10mm), where the calcaneus osteocomma was attached to, were prepared according to the procedures. The transtibial tunnel of 12 mm in diameter, which was angled by 55° from the anteromedial side of the tibia to PCL fixing part/ attachment, was penetrated at PCL tibia fixing part. After penetrating, the specimens of PCL reconstruction were manufactured by the four different fixing methods. Namely, 8 tibia specimens were classified into 4 groups. The first one was the calcaneus fixing of the Achilles tendon by the interference screw (d=10mm, L=30mm) in Fig. 1(a) and the second one was fixed by double cross pins (d=2.7mm, L=42mm, BTB Cross pin kit) in Fig. 1(b). The third one was the soft tissue fixing of the Achilles tendon by the cancellous screw (d=6.5, L=40mm, Depuy Mitek, J&J) and its interference screw(d=10mm, L=30mm) in Fig. 1(c). The fourth one was the soft tissue fixing of the Achilles tendon by double cross pins(d=2.7mm, L=42mm) and the cancellous screw(d=6.5, L=40mm) in Fig. 1(d). The cyclic loading test was performed by Instron 8511. To consider the impact of the killer turn, which can occur in the transtibial tunnel method, the oblique angle of proximal tibia was fixed as 55° to make the real surgery condition using the resin and the possible change of the oblique



(a) PCL-1 in transtibial tunnel with interference screw
(b) PCL-4 in transtibial tunnel with interference screw
(c) PCL-5 in transtibial tunnel with interference screw
(d) PCL-8 in transtibial tunnel with double cross-pin and cancellous screw of soft tissue fixation

Fig. 2 Relationship between failure decrement rate (da/ds) and number of cyclic loading (N) after PCL reconstruction *in interference screw*

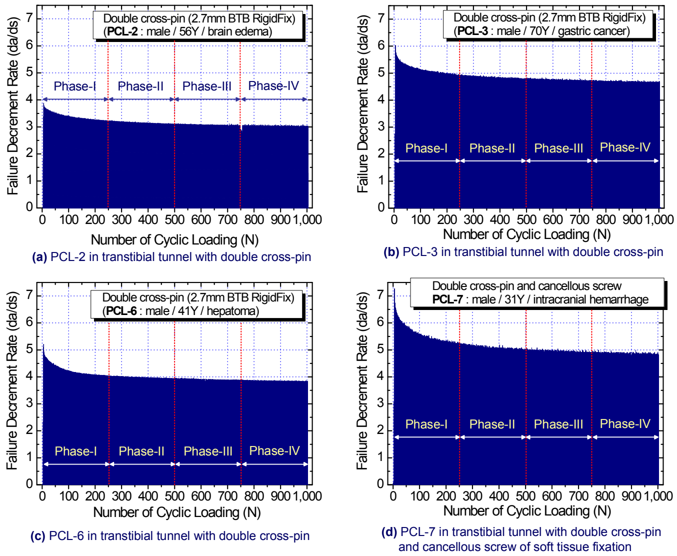


Fig. 3 Relationship between failure decrement rate (*da/ds*) and number of cyclic loading (*N*) after PCL reconstruction *in double cross pin*

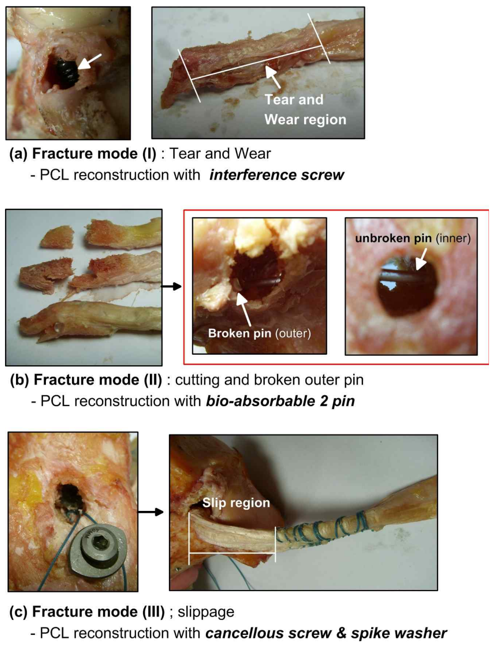


Fig. 4 Failure pictures taken by tnesile stress test *with double cross-pin*(2.7mm biodegradable BTB RigidFix®) in the case of PCL-2, -3, and -6 at the fixation of bone plugs of Achilles tendon and *with double cross-pin and cancellous screw* in the case of PCL-7 at the fixation of soft tissue of Achilles tendon.

angle during the cyclic loading was prevented previously. Referring to the above conditions, both the initial extension and the slippage ratio according to the Achilles tendon fixing device(interference screw vs. double cross pins) and the fixing location of Achilles tendon(calcaneus vs. soft tissue) under the maximum tensile strength(P_{max}) of 250N, the minimum tensile strength(P_{min}) of 50N and the sine loading of 1000 cycle(1 Hz), were evaluated.

3. Ultimate Tensile Strength after Cyclic Loading : The Cases of the Interference Screw and the Double Cross Pins

The fixing method of the Achilles tendon using the interference screw, and it is the fixing method of the Achilles tendon using the double cross pins. PCL-1, PCL-4, and PCL-5 are the interference screws fixed to the calcaneus of the Achilles tendon as shown in Fig. 1(a). PCL-8 shows that the calcaneus was disclosed from the tibial tuberosity of the transtibial tunnel to the distal and the cancellous screw was fixed. At the same time, the interference screw was located at the same point in Fig. 1(a) and it was the double fixation method to fix the soft tissues of the Achilles tendon (hereafter, it refers to soft tissue fixation.). PCL-2, PCL-3 and PCL-6 were made by the insertion of the double cross pin into the calcaneus of Achilles tendon as in Fig. 1(b) and PCL-7 was the insertion of the double cross pin into the soft tissue and the fixation of the cancellous screw to the distal direction of the tibial tuberosity (hereafter, it is called as the soft tissue fixation of the double cross pin.). PCL-1,-2 / PCL-3,-4 / PCL-5,-6 and PCL-7,-8, were made from the left and right knee joints of the same cadaver. When considered the only PCL-5 with excluding PCL-1 and PCL-4 where the Interference screw is dislocated, the total elongation of the Achilles tendon is 5.7 mm. When it is double-fixation method of using the Interference screw (PCL-8) and the Cancellous screw, dislocation of Intereference screw did not occur although elongation was measured at 12.8 mm. The elongation was increased 2.25 times when only the Interference screw is fixed (PCL-5). When compared PCL-5 and PC-8 where there is no dislocation of Interference screw, the initial elongation of PCL-5 occupied 75 % of total elongation (4.5 mm). Also, for PCL-8, the initial elongation occupied 80% of total elongation (10.3 mm). When examining the graph, No relevance with bone density according to age was found. No dislocation of double cross-pin on all specimens was found. When the soft tissue fixation method (PCL-7) of double cross-pin is used, lengthening is 13.7 mm and it is increased 1.8 times than calcaneus fixation method (PCL-6). Among the calcaneus fixation method of double cross-pin, PCL-3 and PCL-6 are in similarity while the PCL-2 shows the 1.7 times of deviation, and it is due to the fact that there is a deviation in each cadaver's mechanical properties. Regardless of that, the ratio of initial elongation in relation to the total elongation is not affected by the above-mentioned 4 fixation methods as presented and the regular ratio shows within the range of 71-82 %. Therefore, it is considered that the fixation method of Achilles tendon has no influence on the intial elongation rate.

4. Conclusions

In this study, initial elongation behavior according to the fixation device and location of Achilles tendon under cyclic loading by using the transtibial tunnel surgery with cadaveric Achilles tendon among diverse PCL reconstructions, and the relationship between the total elongation rate and the slippage are examined. In the case of soft tissue fixation of Achilles tendon with interference screw, slippage percentage among total elongation is 58.3% at initial elongation, and decreases to 55.5% at late loading, and the total decrease is 2.8%. On the other hand, at soft tissue fixation of double cross-pin, slippage rate among total elongation is 45.0%, and increases up to 46.0% at late loading, and total increase rate is 1.0%.

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