Analysis of the graft bending angle at the femoral tunnel aperture in anatomic double bundle anterior cruciate ligament reconstruction: a comparison of the transtibia…

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【 学位論文題目 】

Analysis of the graft bending angle at the femoral tunnel aperture in anatomic double bundle anterior cruciate ligament reconstruction: a comparison of the transtibial and the far anteromedial portal technique(解剖学的二重束前十字靱帯再建術における大腿骨骨孔出口での移植腱の曲げ角度の検討 tran

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Introduction

Anterior cruciate ligament (ACL) reconstruction has increasingly focused on the anatomic double-bundle technique, in which the anteromedial (AM) and posterolateral (PL) bundle are separately reconstructed at the center of the anatomic attachment of the AM and PL bundles. It has been reported that the anatomic reconstruction of both the AM and PL bundle can better restore knee stability than a single bundle reconstruction in biomechanical studies. Additionally, recent clinical studies with two years follow up period showed a significantly superior outcome after anatomic double bundle ACL reconstruction. However, there have been some reports of the PL graft partial rupture after anatomic double-bundle ACL reconstruction (7%-11%) because of the excessive stress on the PL graft. Moreover, 3.8% of partial tear of AM grafts was reported in second-look arthroscopic evaluations of anatomic double-bundle ACL reconstruction using transtibial technique. The cause of the graft damage is multifactorial such as the graft diameter, the type of graft, the graft tensioning and fixation, and the impingement of the graft against the intercondylar notch or PCL. One of the factors responsible for graft damage is thought to be the repetitive bending stress on the graft at the femoral tunnel aperture, due to abrasive force at the contact area on the sharp edge of the bone tunnel aperture when the graft is acutely bent and stretched. Consequently, it is important to adopt a technique which minimizes bending stress on the graft at the femoral tunnel aperture. There are two major reported techniques for creating the femoral tunnel, drilling through the tibial tunnel (transtibial technique) and drilling through the far anteromedial portal (far anteromedial portal technique). No studies have examined the three dimensional bending angles of the graft at the femoral tunnel aperture in two

techniques. The purpose of this study is to investigate and compare the three dimensional bending angle of the graft at the femoral tunnel aperture in two techniques by in-vitro cadaveric measurement using a computer simulation.

Materials and Methods

Seven fresh frozen human cadaveric knees were used in this study. Six degrees-of-freedom (DOF) of knee kinematics and knee position data were measured using an electromagnetic device (FASTRAK, Polhemus, Vermont). The system consists of a transmitter which produces an electromagnetic field, and three electromagnetic receivers. Two of the receivers are rigidly fixed to the femur and the tibia. The third receiver is attached to the end of a stylus of our own design, which is used for indicating three dimensional positions.

Calculation of the length of the AM and PL bundle

In order to the assess the stress on the graft, the length between the femoral and tibial attachment sites of the AM and PL bundle were calculated. The acquired positions of the femoral and tibial attachment sites of the AM and PL bundle were connected and the length of each bundles were calculated at every 10 degrees of knee flexion throughout the recorded intact knee motion.

Calculation of the graft bending angle

First, the 6 DOF of the intact knee kinematics before transecting the ACL was measured through the passive knee motion.

Second, the acquired positions of the femoral and tibial attachment sites of the AM and PL bundle were connected. Three dimensional images of the anatomical AM and PL bundle were entered into the computer and regarded as the virtual AM and PL grafts.

Third, the far anteromedial portal was created at 2 cm posteromedial to the standard anteromedial portal and just above the basis of the medial meniscus. The location of the far anteromedial portal was indicated by the stylus and its position data was recorded.

To measure the graft bending angle using the transtibial technique, the extended lines of the virtual AM and PL graft to the femoral side at 90 degrees of knee flexion were acquired as a virtual femoral tunnel. As the graft bending angle at the aperture of the femoral bone tunnel was defined as the angle between the virtual femoral tunnels and virtual grafts, calculations were made at every 10 degrees of knee flexion throughout the recorded intact knee motion.

In addition, the graft bending angle using the far anteromedial portal technique was calculated as follows. The acquired position of the femoral attachment site of each bundle and that of the far anteromedial portal were connected and the virtual femoral tunnel was created along the connecting line to the femoral side at 110 degrees of knee flexion. Each graft bending angle was defined as the angle between this virtual femoral tunnel and the virtual graft, and the graft bending angles were calculated at every 10 degrees of knee flexion in the same way.

Finally, the AM and PL graft bending angles were compared with the transtibial and the far anteromedial portal technique

Results

The length of each bundle was at maximum at full extension of the knee and decreased with increasing knee flexion to 90 degrees. The length of AM bundle was 34.1 ± 5.4 mm (mean ± SD) at full extension of the knee and 27.9 ± 3.5 mm at 90 degrees of knee flexion. The length of the PL bundle was 29.2 ± 6.0 mm at full extension of the knee and 18.8 ± 2.9 mm at 90 degrees of knee flexion.

The relative changes of the length of the AM and PL bundle at full extension of the knee were 22.5 ± 12.1 % and 55.0 ± 18.6 %. The relative change of the length of the PL bundle in the range of 70 degrees to 0 degree of knee flexion was significantly larger than that of the AM bundle. ($P<0.05$)

In the two techniques, the AM and PL graft bending angle reached their maximum at full extension of the knee where both bundles were fully stretched. At full extension of the knee, the AM graft bending angles in the transtibial technique and far anteromedial portal technique were 66.1 ± 3.7 degrees and 59.0 ± 3.6 degrees. The PL graft bending angles at full extension of the knee in two techniques were 72.0 ± 6.1 degrees and 55.9 ± 4.0 degrees. The AM graft bending angles in the transtibial technique were significantly larger than in the far anteromedial portal technique at 0 and 10 degrees. ($P<0.01$) The PL graft bending angles in the transtibial technique were significantly larger than in the far anteromedial portal technique at low flexion angles (0 ~ 50 degrees). ($P<0.01$)

Discussion

We compared the three dimensional bending angles of the graft between the transtibial technique and the far anteromedial portal technique. Our result confirmed the AM and PL graft bending angle in the transtibial technique was significantly larger than that of the far anteromedial portal technique at low flexion angles where the graft was fully stretched. This suggests use of the far anteromedial portal technique might result in lower stress on the graft at the femoral tunnel aperture and therefore reduce graft damage. Consequently, we regard use of the far anteromedial portal technique to be one technique for reducing the graft damage due to the more obtuse at a low flexion angle in the knee.

論文審査の結果の要旨

受付番号	甲　第2004号	氏　名	西本 浩司
論文題目 Title of Dissertation	解剖学的二重束前十字靭帯再建術における大腿骨骨孔出口での移植腱の曲げ角度の検討．Transtibial technique と far anteromedial portal technique の比較 Analysis of the graft bending angle at the femoral tunnel aperture in anatomic double bundle anterior cruciate ligament reconstruction: a comparison of the transtibial and the far anteromedial portal technique.		
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（要旨は１，０００字～２，０００字程度）

近年、できる限り解剖学的に正常 ACL に近い再建を目的として解剖学的二重束前十字靭帯(以下 ACL)再建術が注目され、従来の一重束再建術と比較して良好な成績が報告されている。しかしながら、術後の再鏡視において大腿骨骨孔出口付近での移植靭帯の部分断裂の報告が散見され、これら移植腱の部分損傷の原因の一つとして大腿骨孔の関節内開口部における移植腱の曲げ変形があげられる。

また解剖学二重束 ACL 再建術における大腿骨側骨孔作成方法には主に far anteromedial portal technique (以下 FAM 法)と transtibial technique (以下 TT 法)があげられる。そこで本研究の目的はこの 2 つの手術手技において移植腱の骨孔出口で三次元の曲げ角度を算出し、比較検討することである。

新鮮凍結膝 7 膝を用いた。膝の 3 次元運動、関節内の解剖学的な ACL 付着位置、Far anteromedial portal の位置情報を三次元電磁気センサ(FASTRAK, Polhemus, Vermont)を用いて記録した。このシステムはトランスミッターから発生した電磁波をセンサーが感知し、センサーの位置および向き情報を記録することでレシーバー間の三次元位置情報が計算できるシステムである。記録された位置情報に基づいて、仮想の移植腱および FAM 法、TT 法にて作成された仮想の大腿骨孔方向を算出し、膝屈曲角度に対する移植腱と大腿骨孔の大腿骨孔出口での曲げ角度の変化を解析し比較検討した。また移植腱にかかるストレスを評価するため、解剖学的な ACL 付着位置の 2 点間距離を算出した。

移植腱 の曲げ変形は膝伸展位にて最大となり、最大伸展位での TT 法および FAM 法の曲げ変形はそれぞれ前内側束(以下 AM 束)では 66.1 ± 3.7 度及び 59.0 ± 3.6 度、後外側束(以下 PL 束)では 72.0 ± 6.1 度及び 55.9 ± 4.0 度であり、有意に TT 法での曲げ変形が大きくなった(paired t-test, $P < 0.01$)。ACL 付着位置の 2 点間距離は AM 束、PL 束共に最大伸展位で最大となり、最大伸展位にて AM 束の長さは 34.1 ± 5.4 mm、PL 束の長さは 29.2 ±6.0 mm であった。また膝屈曲角度 90 度での AM 束、PL 束の長さを 1 とした場合のそれぞれの相対的な長さ変化は膝最大伸展位では AM 束は 22.5 ± 12.1 %、PL 束は 55.0 ± 18.6 %となり、膝屈曲角度 0 度から 70 度において PL 束の相対的な長さ変化は AM 束に比べ有意に大きくなった (paired t-test, $P < 0.05$)。

本研究では移植腱の曲げ変形は膝伸展位で最大となり、同時に長さ変化も膝伸展位で最大となった。過去の報告では我々の研究結果と同様に移植腱の長さ変化に関して PL 束では特に伸展位で大きな変化を示すことを報告している。したがって特に PL 束では移植腱が一番緊張している際に曲げ角度が最大となるため、移植腱が大腿骨開口部の骨の鋭い縁で損傷を受ける可能性が考えられた。また移植腱の再鏡視像の評価と術後の前方安定性及び回旋安定性との相関関係が報告され、移植腱の部分損傷を防止するのは重要と思われる。本研究では特に PL 束において far anteromedial portal technique を使用することにより、伸展位での曲げ変形を有意に小さくすることができるため、移植腱にかかる負荷を軽減させる可能性が示唆された。

本研究は、解剖学的二重束 ACL 再建術における大腿骨骨孔出口での移植腱の曲げ変形について研究したものであるが、従来ほとんど行われていなかった移植腱の三次元的な曲げ変形の算出及び比較を行うことにより、移植腱の曲げ変形を小さくするための大腿骨骨孔作成方法について重要な知見を得たものとして価値ある業績であると認める。よって本研究者は、博士（医学）の学位を得る資格があるものと認める。