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Original Article

Length Difference of Anteromedial and Posterolateral Bundles of Anterior Cruciate Ligament in Flexion and Extension (Cadaver Study)

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ABSTRACT

We aimed to measure lengths of both anteromedial (AM) and posterolateral (PL) bundles of anterior cruciate ligament (ACL) in flexion and extension, and analyse statistically. 20 knees of 10 human cadavers were studied in Republic of Turkey Ministry Of Justice Forensic Medicine Institute. All the subjects were male (100%). An anterior longitudinal incision was made and After passing subcutaneous tissue, knee joint was visualized with a medial parapatellar approach. Lengths of both AM and PL bundles of ACL in flexion and extension were measured in millimetres with flexible ruler scale. Data was analysed statistically. Wilcoxon test was used for statistical analysis. Mean age was 46.5 (32-62). A statistically significant difference was seen in lengths of both AM and PL bundles of ACL in flexion and extension ($p<0.05$). Difference in lengths of bundles of AM and PL in flexion and extension is statistically significant. Whereas, any statistical difference was not noted in comparison of length differences among bundles during flexion and extension ($z=0.085$, $p=0.932$). Difference in lengths' of bundles of AM and PL in flexion and extension was seen statistically significant in our study. In single-bundle technique, only AM bundle of ACL is reconstructed. Besides, both AM and PL bundles of ACL are reconstructed in double-bundle technique. AM and PL bundles have distinct features and lengths in different flexion degrees. We emphasize to review this entity while determining reconstruction technique for ACL-deficient patients.

Key words: *Anterior cruciate ligament, anteromedial bundle, posterolateral bundle, length difference*

Fleksiyon ve Ekstansiyonda Ön Çapraz Bağın Anteromedial ve Posterolateral Bandllarının Uzunluk Farkı

ÖZET

Çalışmamızda ön çapraz bağın (ÖÇB) anteromedial (AM) ve posterolateral (PL) bandlarının fleksiyon ve ekstansiyon esnasındaki uzunluklarını ölçmeyi ve istatistiksel olarak incelemeyi amaçladık. T.C. Adalet Bakanlığı Adli Tıp Kurumunda 10 kadavranın hem sağ hem de sol dizi olmak üzere toplam 20 kadavra dizi üzerinde çalışıldı. 10 kadavranın tümü erkekti (%100). Diz anterior longitudinal insizyonla girildi. Cilt, cilt altı geçildikten sonra medial parapatellar insizyonla diz eklemine ulaşıldı. Ön çapraz bağ, AM ve PL bandlarınının fleksiyon ve ekstansiyondaki uzunlukları milimetrik fleksibl cetvel kullanılarak ölçüldü. Elde edilen veriler istatistiksel olarak değerlendirildi. İstatistiksel çalışmada wilcoxon testi kullanıldı. Ortalama yaş 46,5'tu (32-62). AM ve PL bandların fleksiyon ve ekstansiyon esnasındaki uzunlukları arasında anlamlı fark saptandı ($p<0,05$). ÖÇB'nin AM ve PL bandlarının boyları fleksiyon ve ekstansiyonda istatistiksel olarak anlamlı olarak değişmektedir. ÖÇB'nin AM ve PL bandlarının fleksiyon ve ekstansiyon esnasında oluşan uzunluk farkları birbirleri arasında incelendiğinde ise anlamlı fark saptanmadı ($z=0,085$, $p=0,932$). Çalışmamızda AM ve PL bandların fleksiyon ve ekstansiyon esnasındaki uzunlukları istatistiksel olarak anlamlı değiştiği görüldü. Tek bant yöntemi ile yapılan ön çapraz bağ rekonstrüksiyonunda ön çapraz bağın sadece anteromedial bandı rekonstrükte edilir. Çift bant tekniğinde ise ön çapraz bağın hem anteromedial hem de posterolateral bandları rekonstrükte edilmektedir. AM ve PL bandlar farklı fleksiyon derecelerinde farklı davranış sergilerler ve uzunluklarında farklılıklar meydana gelir. Ön çapraz bağ yaralanması olan hastalarda ön çapraz bağ rekonstrüksiyon tekniği belirlenirken bu bilgilerin göz önünde bulundurulması gerektiğini düşünmekteyiz.

Anahtar kelimeler: *Ön çapraz bağ, anteromedial bandl, posterolateral bandl, uzunluk farkı*

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INTRODUCTION

Anterior cruciate ligament (ACL) is the most important structurethat prevents anterior slippage of the knee joint. Also ACL aids to rotational stability of knee. ACL is most frequently injured structure of the knee joint following menisci(1). Conventional single-tunnel, anatomical single-tunnel and double-tunnel ACL reconstruction methods are commonly applied surgical techniques nowadays. Insingle-bundle ACL reconstruction technique only the anteromedial (AM) bundle is reconstructed, however, in double bundle ACL reconstruction technique both AM and posterolateral (PL) bundlesare reconstructed(2). In this cadaveric study we aimed to measure the length differences of AM and PL bundles during flexion and extension of the knee joint, and analyzethese values statistically in the light of the literature.

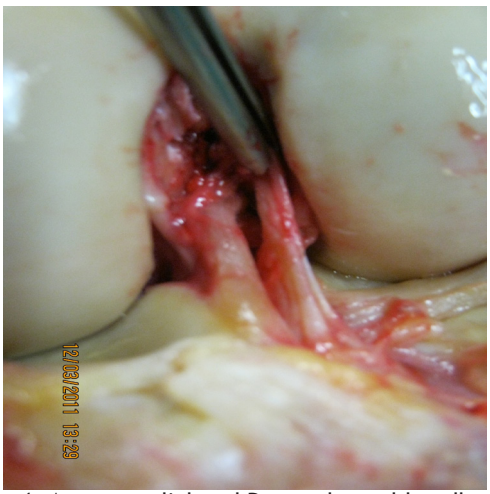

Figure 1. Anteromedial and Posterolateral bundles of Anterior Cruciate Ligament.

MATERIALS AND METHODS

This study includes the evaluation of ACL structure of 10 cadavers at Republic of Turkey, Ministry of Justice, Council of Forensic Medicine. Both left and right knees of 10 cadavers(total of 20 knees) were included to the study. All cadavers were male. Mean age was 46.5 years (range32-62) (Table 1). Cadavers with knee trauma history were excluded. None of the cadavers hadscar tissue at lower extremities that claims previous injuries. Full range of motion of knee joint weredetected in all cadavers. All cadavers were studied at first 36 hours after death. The demographic info like age, height and weight werenoted. All cadavers died due to motor vehicle traffic accident. The incision line was marked with a pen while the cadaver was laying supine position on the operation table. Knee anterior longitudinal incision was performed. After skinincision, a medial parapatellar knee incision was performed to reach the knee joint. The patellasweredeviated laterally. ACLs were identified andAM and PL bundleswere dissected with a hemostatclamp. AM and PL bundles'lengths were measured with using a flexible ruler at 0˚extension and140˚ flexion angles (Figure 1).

Table 1. *Age, height, weight and body mass index information of cadavers.*

Cadever No	Age (years)	Height (cm)	Weight (kg)	BMI
Cadaver 1	32	170	65	22,4
Cadaver 2	39	175	70	22,8
Cadaver 3	55	174	55	18,2
Cadaver 4	45	178	65	20,5
Cadaver 5	36	180	75	23,1
Cadaver 6	42	182	80	24,1
Cadaver 7	58	172	75	25,4
Cadaver 8	62	177	79	25,2
Cadaver 9	53	180	89	27,4
Cadaver 10	43	182	90	27,1
MEAN	46,5	177	74,3	23,6

RESULTS

Lengthsof AM and PL bundles of ACL were measured inmilimeters with using a flexible ruler at extension and flexion positions. Data were noted seperately for each left and right knees of objectives (Table 2). A total of 20 knees of10 cadavers' bundle lengths were measured. Both AM and PL bundlelenghts of ACL at flexion and extension positionswere analyzed statistically (Table 3). Wilcoxon test was used for statistical study. Statistical significance level of $p < 0.05$ was considered significant. Significant differencesin the lengths of AM and PL bundles during flexion and extension was detected ($p < 0.05$) (Table 3). During flexion and extension statistically significant difference noted each of the AM and PL bands'lengths (measurement like 'PL length in extension and flexion'). When compared to eachother there were no significant difference detected between them (measurement like 'AM and PL band length in flexion') ($z = 0.085$, $p = 0.932$). There were no significant differences detected between right and left knee of each cadavers ($p > 0.05$) when compared with the AM and PL bundlesof

***Table 2**. Lengths of Anteromedial and Posterolateral bundles of Anterior Cruciate Ligament in Flexion and Extension*

	L AM BUND. FLEX.	L AM BUND. EXT.	L PL BUND. FLEX.	L PL BUND. EXT.	R AM BUND. FLEX.	R AM BUND. EXT.	R PL BUND. FLEX.	R PL BUND. EXT.
Cadaver 1	38	29	37	25	36	28	35	26
Cadaver 2	37	28	32	25	38	27	31	24
Cadaver 3	38	22	30	20	38	21	29	18
Cadaver 4	36	26	34	24	37	28	34	26
Cadaver 5	37	29	35	26	36	28	34	26
Cadaver 6	39	30	36	27	38	29	36	26
Cadaver 7	36	27	33	24	36	28	34	24
Cadaver 8	37	28	34	23	37	29	33	25
Cadaver 9	39	30	35	25	38	29	34	25
Cadaver 10	38	29	34	26	39	30	35	25
MEAN	37,5	27,8	34	24,5	37,3	27,7	33,5	24,5

right and left knee's ACL (Wilcoxon test) (Table 4).

The relationship between the lengths of the AM and PL bundlesandage, height, weight, and body mass index were analysed. Statistical analysis was performed with using Spearman's rho analysis. Significant level of p value was detected($p < 0.01$). No statistically significant difference detected between the lengths of the AM and PL bundlesandage, height, weight, and body mass index ($p > 0.01$).

DISCUSSION

ACL is most frequently injured structure of knee joint following menisci. ACL injuries are most common ligament injuries around the knee joint(1). There are many alternative surgical techniques and graft material options for reconstruction of ACL(2). ACL reconstruction surgery is not applied to correct the muscular functions, but it may cause knee instability when left untreated. Stability of knee joint is important but there is no evidence about protective effect of ACL reconstruction to prevent the development of further arthritis (3). ACL seems like a unique ligament macroscopically. It consist of two separate functional bundles,AM and PL bundles. AM bundleis a stabiliser like a barrier of the knee and prevents anterior translation of the joint at flexed position (4). It has maximum tension at flexion position of the knee. It isn't functionally active and doesn'trestore normal knee laxity andkinematics at extension posture (5). Experimental studies showed that in cases of double-band ACL reconstruction, the load on the AM and PL bands varies in different degrees of knee flexion (6). These findings implythat each bundle has biomechanically different behavior in certain circumstances. We evaluated the lengthchanges of these bundles in different degrees of flexion and extension. Woo et al demonstrated that the ACL exhibits different behaviours at different degrees of flexion when non-axial tensile forces applied (7). ACL reaches most stretched and tense position at 30 degrees of knee flexion. This means that the fibriller structure of the ACL is varying with different flexion degrees (7). Hosseini and his colleagues examined the ACL's relative lengthening under full weight bearing condition. They didn't detect an absolute opposite behaviour like one of the bands is

***Table 3**. Statistical analysis of leght difference between bundles*

	Mean	SD	Avarage dif.	SD dif.	Wilcoxon test	Wilcoxon test
L AM Bundle Flex.	37,5	1,08			z	P
L AM Bundle Ext.	27,8	2,394	9,7	2,263	-2,911	0,004
L PL Bundle Flex.	34	2				
L PL Bundle Ext.	24,5	1,958	9,5	1,434	-2,818	0,005
R AM Bundle Flex.	37,3	1,059				
R AM Bundle Ext.	27,7	2,497	9,6	2,757	-2,84	0,005
R PL Bundle Flex.	33,5	2,068				
R PL Bundle Ext.	24,5	2,415	9	1,247	-2,82	0,005

Table 4. *Statistical analysis of leght difference between bundles at flexion and extension position.*

	Mean	SD	Avarage dif.	SD dif.	Wilcoxon test	Wilcoxon test
L AM Bundle Flex.	37,50	1,080			z	P
R AM Bundle Flex.	37,30	1,059	,200	1,033	-0,632	,527
L AM Bundle Ext.	27,80	2,394				
R AM Bundle Ext.	27,70	2,497	,100	1,197	-0,277	,782
L PL Bundle Flex.	34,00	2,000				
R PL Bundle Flex.	33,50	2,068	,500	,972	-1,508	,132
L PL Bundle Ext.	24,50	1,958				
R PL Bundle Ext.	24,50	2,415	,000	1,333	-0,087	,931

lengthening while the other shortening. But each bundle was acting differently. The PL bundlewasshorter than AM bundle. However, the relative elongation of the AM bundleis higher than the PL bundle. Elongation of ACL is not much, but the PL bundle of this ligament relatively lengthensup to 13% under the weight of the entire body. According to these data ACL'sbiomechanical behaviourhaveto be examined at three-dimensional point of view. Some authors has suggested that it is impossible to restore the original structure and three dimensional biomechanical behaviours with current techniques like single or double band reconstructions (8). In our study we measured both AM and PL bundlelengths of ACL inflexion and extension positions with non-weight bearing conditions in different flexion degrees. These values were analyzed statistically (Table 3). Significant difference between the lengths of AM and PL bundles during flexion and extension was detected with Wilcoxon test ($p < 0.05$) (Table 3). During flexion and extension statistically significant difference noted each of the AM and PL bands' in different angles.

At routine single-bundle ACL reconstruction technique only the AM bundle is reconstructed. In this study, although the length differences between AM and PL bundles' are not statistically significant inflexion and extension ($p > 0.05$), lengths of AM and PL AM and PL bundles's changed significantly ($p < 0.05$) during flexion and extension. We think that ACL reconstruction with double-band technique contributes more stability during flexion and extension of the knee. Because the double-AM and PL bundle technique additionallyreconstruct the PL bundleunlike the single-bundle method. Studies shown that PL band contribute to stability. The small sample size, not evaluating the behaviour of ACL under effects of different loads, andnot evaluating the effect of other knee ligamentswere the weak points of our study.

The clinical behaviour of AM and PL bundles differ in different flexion degrees. So the adequate ACL functional restoration is impossible by reconstruction of one bundle. Due to this reality the surgeon should reconstruct the ACL as physiologic as possible. According to data obtained in this cadaveric study, ACL appears like a single bundle but it consists of two separate functional bundles. AM and PL bundles exhibit different behavioursand different lengths in different flexion angles of the knee. Before determination of the optimal treatment method for ACL injury cases, these information should be taken into consideration for selecting ACL reconstruction technique.

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