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Clinical importance of femoral and tibial tunnel localizations in arthroscopic anterior cruciate ligament reconstruction

Artroskopik diz ön çapraz bağ onarımında femoral ve tibiyal tünellerin konumunun önemi

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Objectives: The aim of this study is to evaluate the effect of femoral and tibial tunnel localizations on knee functions after arthroscopic single bundle anterior cruciate ligament (ACL) reconstruction and to contribute to the definition of the ideal tunnel localizations for the best results.

Patients and methods: Thirty knees of 30 patients (29 males, 1 female; mean age 28.4 years; range 20 to 43 years) who underwent hamstring autograft reconstruction with the transfemoral fixation technique due to isolated complete rupture of the ACL were retrospectively evaluated. All of the operations were performed by the same surgeons and in the same institution. Tunnel localizations were defined according to the Harner Quadrant method in the post operative period. Mean follow-up period was 19.6 months and postoperative Lysholm knee scores and joint range of motion values were noted. The correlation between tunnel parameters and the scores were statistically evaluated.

Results: When all parameters were considered it was found out that the tunnel localizations in the sagittal tibial plane solely and independently had a significant effect on knee functions.

Conclusion: It was concluded that especially the tibial tunnel located sagittally in the anterior second half of the plateau improves the knee functional scores after ACL reconstruction.

Key words: Anterior cruciate ligament reconstruction; tunnel localization; arthroscopy.

Amaç: Bu çalışmada artroskopik ön çapraz bağ onarımında femoral ve tibiyal tünel yerleşiminin ameliyat sonrası dönemde diz işlevleri üzerine olan etkisi araştırıldı ve başarılı bir ön çapraz bağ (ÖÇB) onarımı için gerekli ideal tünel yerleşiminin yeri belirlendi.

Hastalar ve yöntemler: Bu çalışmada, izole tam ÖÇB kopması nedeniyle transfemoral tespit ile hamstring otogreft rekonstrüksiyonu uygulanan 30 hastanın (29 erkek, 1 kadın; ort. yaş 28.4; dağılım 20-43) 30 dizi retrospektif olarak değerlendirildi. Ameliyatların hepsi aynı ekip tarafından aynı kurumda gerçekleştirildi. Ameliyat sonrası dönemde hastaların hepsinin tünel yerleşimleri, radyografik olarak Harner quadrant yöntemine göre belirlendi. Ortalama 19.6 ay takip edilen hastalarda ameliyat sonrası Lysholm diz skorları ve eklem hareket açıklığı değerleri kaydedildi. Tünel parametreleri ile skorlar arasındaki ilişki istatistiksel olarak değerlendirildi.

Bulgular: Tüm parametreler incelendiğinde, sadece sagittal plandaki tibiyal tünel yerleşiminin diğerlerinden bağımsız olarak diz işlevleri üzerinde anlamlı etkisi olduğu gösterildi.

Çıkarımlar: Başarılı bir ÖÇB onarımı için özellikle tibiyal tünelin sagital planda ön ikinci bölüme yerleşiminin etkili olduğu ve onarım sonrası diz fonksiyon skorunu artırdığı sonucuna varıldı.

Anahtar sözcükler: Ön çapraz bağ rekonstrüksiyonu; tünel lokalizasyonu; artroskopi.

Although there are many studies[1-9] conducted on tibial and femoral tunnel localizations in anterior cruciate (ACL) reconstruction, the ideal localizations of the tunnels are still controversial. This is because of the complex anatomy of the anterior cruciate ligaments' origo and insertio. Most of the studies[3,9-14] in the literature generally focus on the proximal or distal localization of the femoral

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tunnel, isometrical localization, divergence of the tunnels and reconstructing the anterior cruciate ligament more medially or more laterally than the posterior cruciate ligament. In the light of the data gained from these studies, it is concluded that the determining factor for the failure of the graft reconstruction is locating the femoral tunnel more anteriorly than the origo of the ligament itself. The tibial tunnel localization became more important in recent times. Goble et al.[15] reported that it is necessary to locate the graft more anteriorly than its original position on tibia to avoid an anterior displacement of tibia, Howell and Clark,[16] on the other hand, claimed that the posterior localization of the tibial tunnel was more essential to avoid femoral impingement. Jepsen et al.[3] reported that the most common error was a femoral placement anterior to the anatomical insertion of the ACL. Their functional scores declined with the increasing distance of the graft from the most isometric bundle of the ACL in the anteroposterior direction. Topliss and Webb[1] reported the tunnel misplacement to be the most common technical error, which leads to graft failure; femoral tunnels placed too anteriorly appearing to be the most critical of these errors. Sudhahar et al.[17] claimed that the reason for poor correlation in the tibial tunnel positions might be the mobile non-anatomical landmarks not reflecting the actual 3D bony anatomy.

In this study, we aimed to find the effects of the tibial and femoral tunnel localizations on knee functions and to contribute to the definition of the ideal tunnel localizations. For this purpose, we investigated a nearly homogeneous patient group with isolated complete ACL ruptures that received the same treatment modality preoperatively and postoperatively with the same technique and instruments used by the same crew. We tried to keep the tunnel placements as the only variables to evaluate the effect of the localization data on knee scores accurately.

Our hypothesis is that the tibial tunnel localization is as important as the femoral tunnel location in ACL reconstruction.

PATIENTS AND METHODS

Between 03.01.2006 and 20.12.2006, single bundle ACL reconstructions were arthroscopically performed using hamstring autografts and a transfemoral fixation device in 30 knees of 30 patients (29 males, 1 female; mean age 28.4 years; range 20 to 43 years) with isolated complete ACL rupture. There was no other intraarticular pathology except for the ACL rupture in the patients. All of the operations were performed by the same crew in the same institution. Preoperative, postoperative and final controls were performed by the senior author. Seven of the patients were affected on the left side and the others were affected on the right. All of the patients were operated under spinal anesthesia using a pneumatical tourniquet. The mean duration of hospitalization was four days. Mean follow-up period was 19.6 months.

Routine notch-plasty procedure and debridement of the remainings of the ligament were performed in all of the cases. Femoral and tibial tunnels were reamed using traditional methods according to the thickness of the hamstring grafts derived. The tibial tunnel was drilled through a guide pin, using a fully fluted reamer. After the tibial tunnel was rasped and when the knee was hyperflexed, the femoral guide pin was inserted through the tibial tunnel using the femoral offset guide that is selected appropriately according to the graft thickness. The femoral tunnel was drilled by reaming over the guide pin. A transfemoral fixation device was used for femoral fixation after the hamstring autograft was prepared in routine fashion and placed in the tunnels. Following the femoral fixation, the knee was tested with flexion and extension movements to see if the graft movement was less than two mm in the tibial tunnel as Höher et al.[18] also described in their study. The tibial fixation was applied using a bio-absorbable screw and a U-staple when the knee was extended at -10 degrees and a manual posterior drawer force was applied. The patients wore a knee brace with an angle adjustable hinge in the early postoperative period. The patients were allowed to flex their knees 90 degrees at the end of the first postoperative week and 120 degrees at the end of the 3rd postoperative week. After the 3rd week, the patients were off the braces and started active quadriceps exercises. In the postoperative period, the patients were evaluated at every week till the end of the first postoperative month and after that in the 3rd and the 6th months and at the end of the first postoperative year in the outpatient clinic. During the controls, AP and lateral radiographies of the operated knee were obtained. The knee examinations were performed and Lysholm scores and joint range-of-motion (ROM) values were noted. Tunnel positions were evaluated on the radiographies according to Harner's quadrant method. Tibial plateau and femoral intercondylar notch roof were divided in four equal quadrants in antero-posterior and sagittal plaines on the Blumensaat's line. These quadrants were identified as 'a-b-c-d' from anterior to posterior and from medial to lateral (Figure 1, 2). The quadrant on which the mid-line that divided the tunnels in two equal parts was located was noted. The localization of the femoral tunnel on the anterior-posterior plane was noted as the value which the mid-line that divided the tunnel in two equal parts showed on the hour plate image.

RESULTS

During the final controls, the mean knee flexion degree was found to be 136.3° (range; 110°-160°). Except for an extension loss of 5 degrees in three cases, extension was full in all cases. The mean postoperative Lysholm score was found as 80.3 in the study group (range; 25-95, median value 85) (Table I).

The localizations of the femoral and the tibial tunnels in anteroposterior (AP) and lateral radiographies and the knee scores of the cases were noted (Table II). The correlation between the tunnel positions and the knee scores were evaluated with a threestep statistical analysis. First non-parametric correlation, then regression analysis and at last univariate analysis of variance methods were performed to analyze the effect of the variants on the scores independently. It was only concluded that it had a significantly positive effect on knee scores ($p<0.001$) when the tibial tunnel was localized on the quadrant 'b' meaning that placing the tibial tunnel in the 25-50% of the tibial plateau sagittally improved the knee scores.

DISCUSSION

In our study, the tibial tunnel localization was found to be an important point to consider in order to obtain good results after the ACL reconstruction. In a study of Romano et al.,[19] a logistic regression analysis revealed that the more anterior the placement of the tibial tunnel, the greater the loss of both flexion and extension. In the 21 patients with full extension but flexion <130 degrees, placement of the tibial tunnel tended to be more medial (average, medial 40% of the tibia) than in the 65 patients without flexion deficit (average, medial

Figure. 1. Femoral and tibial tunnel localizations of a 33 year old male in the anteroposterior plane.

Figure. 2. Femoral and tibial tunnel localizations of the same patient in the sagittal plane.

TABLE I

Demographics and findings of the patients

No	Age/Sex	Side	Follow-up-months	Flex	Ext.	Lysholm
1	26/M	L	26	130	Full	87
2	33/M	L	20	140	Full	93
3	23/F	L	14	150	Full	95
4	37/M	R	24	130	Full	88
5	25/M	R	19	130	Full	63
6	43/M	R	13	145	-5	89
7	21/M	R	20	140	Full	85
8	23/M	R	16	145	Full	85
9	30/M	R	23	160	Full	95
10	33/M	R	18	135	Full	89
11	23/M	R	16	130	Full	77
12	27/M	R	16	124	Full	65
13	21/M	R	18	130	Full	85
14	31/M	R	19	140	Full	88
15	30/M	R	26	110	-5	25
16	37/M	R	21	148	Full	88
17	28/M	R	21	138	Full	63
18	26/M	R	27	115	Full	60
19	20/M	R	18	140	-5	89
20	33/M	R	15	125	Full	84
21	20/M	L	23	135	Full	85
22	23/M	L	17	145	Full	76
23	33/M	L	18	128	Full	87
24	32/M	L	18	136	Full	72
25	30/M	R	17	145	Full	83
26	20/M	R	22	140	Full	76
27	29/M	R	25	145	Full	95
28	28/M	R	19	140	Full	75
29	29/M	R	21	135	Full	85
30	27/M	R	20	130	Full	80

45% of the tibia). They concluded that the placement of the tibial tunnel in the 'eccentric' anteromedial position may contribute to the development of flexion and extension deficits after anterior cruciate ligament reconstruction. In our image, the values obtained during the last controls were evaluated statistically, In this study we concluded that when the tibial tunnels are located in the anterior second quadrant (quadrant 'b'), the Lysholm scores were influenced significantly positively and no flexion deficits were observed.

Khalfayan et al.[2] presented in their study that clinical results correlated positively with posterior femoral tunnel placement on lateral radiographs and negatively with excessive anterior tibial tunnel placement. Sommer et al.[20] concluded that it is possible to improve the clinical result in single bundle ACL reconstruction by lowering the tibial tunnel angle and thereby lowering the femoral tunnel toward the 2-O'clock position. Moisala et al.[4] reported the Lysholm score was better when the femoral graft placement was more posterior. The optimal femoral graft position was between 25% and 29% of the length of the femoral condyle along the Blumensaat's line from posterior to anterior. The optimal tibial graft placement was between 32% and 37% of the length of the tibial plateau from the anterior corner and the optimal sum-score was between 61 and 66. The best out-

TABLE II

Femoral and tibial tunnel localizations of the patients and the Lysholm scores

Lateral F.T.	Lateral T.T.	Ap.F.T.	Ap.T.T.	Lysholm score
d	b	11	c	93
d	b	11	c	85
c	b	11	b	85
d	b	11	c	63
c	b	1	c	89
c	b	11	b	65
d	b	11	c	95
c	b	11	c	88
d	b	11	c	87
c	b	11	c	88
c	b	10	c	89
d	b	11	c	89
d	c	12	c	83
d	b	1	c	72
c	b	11	c	88
c	b	11	c	87
d	c	1	c	76
d	b	1	c	79
c	c	11	b	25
b	b	10	c	77
d	b	1	c	95
c	b	1	c	86
b	c	12	b	60
d	b	11	c	96
c	b	11	b	63

FT: Femoral tunnel; TT: Tibial tunnel; ApFT: Anteriorposterior femoral tunnel; ApTT: Anteriorposterior tibial tunnel.

come was achieved when the sum-score was small; i.e. the graft placement showed posterior enough in the femur and anterior enough in the tibia. Bernard et al.[10] claimed that the ACL can be found just inferior to the most superior-posterior quadrant; in anatomic terms it is localized from the dorsal border of the condyle at approximately a quarter of the whole sagittal diameter of the condyle and from the roof of the notch at approximately a quarter of the notch height. Loh et al.[11] reported that the 10 O'clock position more effectively resisted rotatory loads when compared with the 11 O'clock position as evidenced by smaller anterior tibial translation and higher in situ force in the graft. Despite the fact that ACL grafts placed at the 10 or 11 O'clock positions are equally effective under an anterior tibial load, neither femoral tunnel position was able to fully restore knee stability to the level of the intact knee. Markolf et al.[12] stated that AP positioning of the femoral tunnel at the 11 O'clock positioning is more critical than the 10 O'clock positioning in terms of restoring normal levels of graft force and knee laxity profiles at the time of ACL reconstruction. In our study, although the AP tunnel placement was generally at the 11 O'clock position, this did not statistically effect the scores independently.

Boden et al.[5] claimed that laxity was minimal when the center of the femoral tunnel was 6 mm below the intercondylar notch roof and 2.5 mm behind the posterior margin of the notch. In a study of Muneta et al.,[21] the results indicated that the knee joints in which the tibial drill hole was positioned laterally from the medial intercondylar tubercle or in which the tibial drill hole was positioned anteriorly to the Blumensaat's line showed a tendency to develop more postoperative chronic synovitis. The knees in which the tibial drill hole was positioned anteriorly to the Blumensaat's line also showed larger AP laxity. Lee et al.[13] reported that the vertical orientation of the femoral tunnel in the axial plane is closely related to residual pivot shift without definite anteroposterior laxity. More oblique positioning of the graft may have advantages in rotational stability, which in turn increase subjective patient satisfaction.

Howell et al.[22] claimed that to prevent ACL graft impingement, roof-plasties need to be performed in both acute and chronic ACL reconstructions if the presently accepted locations for positioning the tibial tunnel are used. A more anteriorly placed tibial tunnel requires more bone removal to prevent roof impingement than a more posteriorly positioned tibial tunnel. However, Höher et al.[18] claimed that there was no difference between the non-roofplasty and roofplasty groups. Amis et al.[6] concluded that the tibial attachment must be posterior enough to avoid graft impingement against the femur. Additionally, poor graft placement on the femur leads to excessive changes of the graft attachment site separation distance as the knee flexes, and the worst case corresponds to the attachment being too far anterior. Goble et al.[15] found the superior femoral notch impingement to be the most significant reason for graft failure. A 3 mm anterior shift of the tibial tunnel will usually result in notch impingement. For that reason, they recommended that the tibial tunnel be drilled primarily to accomplish the desired tunnel size and to prevent anterior tibial tunnel axis shift. We performed the notchplasty procedure routinely in all of our 30 patients. Therefore we can not statistically evaluate the correlation between notchplasty and knee scores as we do not have a control group on which we did not perform notchplasty. However, we did not encounter any motion restriction or pain that may clinically indicate notch impingement in any of the cases.

C-arm flouroscopy devices and robotic systems may improve tunnel accuracy. We did not use flouroscopy or robotic devices during our operations. However, when the literature is reviewed, we see that there are promising studies especially on robotic systems. Burkart et al.[7] showed that the direction of the tunnels drilled in the femur and tibia differed in the robotic and traditional techniques. Still the robotic system had the most consistent tunnel directions, while the surgeon's tunnels were more dispersed. Musahl et al.[8] reported that the active robotic system was highly accurate for tunnel placement during the ACL reconstruction, meaning that the robot drilled the tunnels very close to the surgeon's plan. Comparison to a control group of surgeons could not be made because no preoperative plan is usually created in traditional surgery. Klos et al.[23] claimed that graft placement and variability was reduced significantly with computer overlays added over flouroscopic visualization.

In their study, Sudbahar et al.[17] wanted the surgeons to mark the tunnel localizations they drilled during surgery on preoperative knee graphies just after the surgery and compared these drawings with the original tunnel localizations seen on postoperative radiographies. Authors found out that the surgeons' ability to predict femoral tunnel localizations was better than predicting that of the tibial tunnels. Therefore they claimed that it was better to drill tibial tunnels with flouroscopic assistance during surgery. In their study, Zavras et al.[9] confirmed the existence of an isometric zone close to the posterior end of Blumensaat's line at the furthest posterior extremity of the femoral intercondylar notch, close to the 'over the top' position under several loading conditions and other graft attachment points are less suitable for ACL reconstruction. Musahl et al.[14] claimed that, knowing that the ACL is a complex anatomical structure not obeying the rules of isometry, a femoral tunnel position inside the anatomical footprint of the ACL resulted in knee kinematics closer to the intact knee than did a tunnel position located for best graft isometry. In their study, Yamamoto et al.[24] showed that it was not possible to provide a completely isometrical graft with any femoral placements. However Musahl et al.[14] referred to Zavras's study and they reported that the closest femoral tunnel localization to Blumensaat's line could achieve the most isometrical results. Musahl et al.[14] referred to Markolf's study and they found out that placing the femoral tunnel more anteriorly than the ACL's original anatomical insertio required more power to balance the graft. Musahl et al.[14] evaluated if there was any difference between drilling the femoral tunnel on ACL's original anatomical insertio and drilling it on the point that provided the best graft isometry. Authors showed that ACL reconstructions never provided normal knee kinematics; however, they found out that the femoral tunnel that is drilled on the original insertio of the ACL was better in providing better knee kinematics than the one drilled on the point where graft isometry was the best. We think that classical tunnels drilled with traditional methods are more appropriate for isometrical fixation, because in the light of our clinical experience, it seems more difficult to accommodate mobile anatomical landmarks than forming the tunnels by observing the graft tightness and motion on the points closest to femoral and tibial isometrical areas. In consequence, we attached more importance on graft isometry by using traditional surgical techniques.

As a conclusion, although there are many studies made on tibial and femoral tunnel localizations in ACL reconstruction, the ideal localization of the tunnels are still controversial. Although we had some limitations in our study such as the retrospective nature of the study, the lack of the data about preoperative Lysholm scores and ROM values and the relatively short follow-up period, we achieved a statistically significant result in the end. It had a significantly positive effect on knee scores ($p<0.001$) when the tibial tunnel was localized on the quadrant 'b', meaning that placing the tibial tunnel on the 25-50% of the tibial plateau sagittally improved the knee scores. Thus, one must consider locating the tibial tunnel anteriorly enough to achieve a good result after ACL reconstruction.

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