Comparison of Transfix Screw Technique and Endobutton Technique in Terms of Tunnel Widening and Clinical Results in Anterior Cruciate Ligament Reconstruction

Ön Çapraz Bağ Rekonstrüksiyonunda Transfiks Vida Tekniği ile Endobutton Tekniğinin Tünel Genişlemesi ve Klinik Sonuçlar Yönden Karşılaştırılması

Abstract

Objective: The aim of the present study was to compare transfix screw technique and endobutton technique in terms of femoral and tibial tunnel enlargement and clinical outcomes in anterior cruciate ligament (ACL) surgery and to discuss nonanatomic transtibial system under current circumstances.

Method: This retrospective study was conducted on 50 patients who had ACL reconstruction in SCI Göztepe Training and Research Hospital between September, 1999 and March, 2003. Among the patients enrolled, 17 patients had endobutton and 33 had transfix screw technique for ACL reconstruction. The mean age of the patients who underwent ACL reconstruction through endobutton technique was 27.2 years whereas the mean age of those who had transfix screw method was 29.9 years. Femoral and tibial tunnel enlargement rates were reviewed for radiological comparison. Harner’s quadrant location, Frontal femoral tunnel angles and Frontal tibial tunnel angles were similar in both groups, and they were found comparable radiologically. The differences between the early postoperative and late postoperative tunnel widths of both groups were compared. Clinical comparison was performed through the Hospital for Special Surgery Knee score (HSSKS).

Results: Tunnel widening was detected in a significant part of the cases who had both endobutton and transfix screw methods; and the cases with a tunnel dilatation difference at and over 2 mm were accepted as tunnel enlargement and evaluated in consideration of standard deviation. Consequently, significant tunnel enlargement was detected in 47% of the cases in endobutton continuous loop (CL) reconstruction group and 51.5% of the cases in transfix screw reconstruction group. The differences between the early postoperative and late postoperative tunnel widths of both groups were compared. Clinical comparison was performed through the Hospital for Special Surgery Knee score (HSSKS).

Bulgular: Hem endobutton hem de transfiks olgularının önemli bir kısmında tunnel genişlemesi bulundu ve standart sapma dikkate alınarak 2 mm ve üzerinde tunnel genişlik farklı olan olgular analamı tunnel genişlemesi olarak kabul edilip değerlendirilmeye alındı. Sonuç olarak endobutton CL'deki olguların 47’sinde, transfiks tekniğindeki olguların 51,5’inde analamı tunnel genişlemesi bulundu. Her iki teknik arasında tunnel genişlemesi bakımından analamı istatistiksel bir fark bulunmamak (p>0,05). Transfiks tekniğinde femoral tunnel genişlik farkı 2 mm ve üzerinde olan 

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amaç: Bizim çalışmalardaki amacımız ön çapraz bağ (ÖÇB) cerrahisinde transtibial sistemle yaptığı transfiks vida tekniği ile endobutton tekniğini radyolojik ve klinik olarak karşılaştırmak ve bugünün koşullar altında tartışmaktır.

yöntem: Çalışma retrospektif olarak SSK Göztepe Eğitim ve Araştırma Hastanesi’nde Eylül 1999 ile Mart 2003 yılları arasında anatomininViolat ÖÇB rekonstrüksiyonu yapılan 50 hastada yapıldı. Bunların 33’si ise transfiks vida tekniği ile ÖÇB rekonstrüksiyonu yapılan hastalardı. Endobutton tekniği ile ÖÇB ameliyatı yapılan hastaların ortalaması yaş 27,2 iken transfiks vida tekniği ile yapılan hastaların ise 29,9’du. Radyolojik karşılaştırımda femoral ve tibial tunnel genişleme oranları bakıldır. Her iki teknipte Harner’s kadran dağılımı, Frontal tibial tunnel açıları ve Frontal femoral tunnel açıları benzer olup radyolojik olarak femoral ve tibial tunnel genişleme oranları karşılaştırılabilir bulundu. Erken postoperatif ve geç postoperatif tunnel genişlik oranları birbiriyle karşılaştırıldı. Klinik karşılaştırıma ise Hospital for Special Surgery Knee Score (HSSKS) ile yapıldı.

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Abstract

in 51.5% of the cases in transfix screw technique group. There was not any statistically significant difference in tunnel enlargement between two techniques (p>0.05). In the transfix technique, the HSKSS scores of the patients with femoral tunnel width difference over 2 mm were 90.2 whereas in cases without femoral tunnel width or minimal, this score was 91.1. In Endobutton technique, HSKSS scores of the patients with the femoral tunnel enlargement were 91, HSKSS scores of the cases without femoral tunnel enlargement were 91,25. There was no relation between femoral tunnel widening and HSKSS scores due to the value of p>0.005 in the Mann-Whitney U test. Postoperative rehabilitation period was similar in both groups; HSSKS scores of the cases who underwent transfix and endobutton techniques were compared (Table 9 and 10). The p>0.05 meant that there was not any clinically significant difference between two groups.

Conclusion: Significant tunnel widening was found in both endobutton CL and transfix technique (using transfibial method) in ACL reconstruction with the hamstring tendon graft. However, there was no significant difference between the two techniques in terms of tunnel widening. It was observed that tunnel enlargement had no significant effect on clinical results in both groups. There was no significant difference between the two groups in terms of clinical results. Successful outcomes were obtained in ACL reconstructions through transfibial technique where extraarticular fixation was done. Recognition of both transfibial techniques for anatomic ACL reconstruction is essential for ACL revision procedures.

Keywords: Anterior cruciate ligament, endobutton technique, transfix technique, transfibial technique, tunnel widening

Introduction

Surgical procedures of anterior cruciate ligament (ACL) gathered speed by the replacement of extraarticular techniques with intraarticular techniques for ACL procedures in 1990s (1,2). ACL reconstruction was performed non-anatomically first; when importance of rotational stability in the knee was noticed after 2000s, anatomic ACL reconstruction procedures started and almost all procedures are performed through anatomic ACL reconstruction approach today. Although successful results are obtained by former transfibial technique, this method has been begun to be forgotten currently. We believe that this method should be recognized in detail and performed compulsorily due to increasing ACL revision surgery rates.

Many problems have been encountered in ACL reconstruction surgery from past to present. One of them is femoral and tibial tunnel enlargement. Many biological and mechanical factors have been blamed for tunnel widening. Antigenic immune response, nonspecific inflammatory reaction, toxic substances created by materials, cell necrosis during the use of drill and synovial cytokines are biological factors that can cause bone tunnel enlargement. Unsuitable tunnel placements, stress loads and movement made by the graft in the tunnel, characteristics of fixation materials, excessive rehabilitation are the factors that are suggested to cause tunnel enlargement as mechanical reasons (3,4). Each of these factors that can reason for tunnel widening may impair bone tendon union. 10% failure and recurrent instability develop after ACL surgeries due to graft non-union.

The aim of the present study was to make a radiological and clinical comparison of transfix screw technique through transfibial system and endobutton technique in ACL surgery of which we used to perform by non-anatomic approach, and to discuss the results under current conditions.

Materials and Methods

This retrospective study was conducted on 50 patients who had ACL reconstruction in SCI Göztepe Training and Research Hospital between September, 1999 and March, 2003. The study was conducted with the consent of all patients. Among the patients enrolled, 17 patients had endobutton and 33 had transfix screw technique for ACL reconstruction. The mean age of the patients who
underwent ACL reconstruction through endobutton technique was 27.2 years whereas the mean age of those who had transfix screw method was 29.9 years. The duration between first trauma and ACL reconstruction was 24.3 months in transfix screw technique, and 30.9 months in endobutton technique. The distribution of meniscus rupture and chondral lesion was similar in two groups. Partial meniscectomy was performed on all of the cases with meniscus rupture.

Bioabsorbable screws with a diameter of 1 mm larger than tibial tunnel diameter were used to fix the tibial tunnels in both groups. One staple was used additionally in transfix technique whereas 2 staples or washers were used in addition to bioabsorbable screw in endobutton technique. The mean follow-up periods were similar in both groups as 2.8 years for transfix screw method and 2.9 years for endobutton technique.

Radiological comparison of both groups was performed by anterior posterior (AP)/lateral X-rays and magnetic resonance imaging of the knee. Frontal femoral tunnel angle (Figure 1), frontal tibial tunnel angle (Figure 2), disintegration angle (Figure 3) and Harner’s quadrants were reviewed by direct X-ray. The angles reviewed and Harner’s quadrant location were similar in both groups, and they were found comparable radiologically. Femoral and tibial tunnel widening ratios were assessed for radiological comparison. Radiological measurement was standardized by placing a square iron of 1 cm² into the film cassette.

Clinical comparison was performed through the Hospital for Special Surgery Knee score (HSSKS). HSSKS is a comprehensive measurement tool including subjective, objective and functional tests. Subjective complaints include pain, swelling, locking, release and frequent release. Objective issues include any previous surgical procedures (i.e. partial menisectomy), date of injury, surgery date, surgical procedure and examination of knee ligaments (Lachman, anterior drawer, posterior drawer tests and pivot shift etc). Functional assessment includes daily activities as well as working status, sports, running, jumping, standing and leaning onto the side. They are evaluated over 100 points. The ranging was assessed as follows; 96 to 100 points, quite good; 91 to 95 points, good; 86 to 90 points, moderate; 76 to 85 points, bad; and below 76, very bad. The highest score (approximately 40 to 50%) was obtained by functional activity and test response of the patient.

**Statistical Analysis**

Mean, standard deviation, median, minimum, maximum value frequency and percentage were used for descriptive
statistics. The Mann-Whitney U test was used for the comparison of quantitative data. Paired sample T test was used to detect standard deviation. SPSS 26.0 was used for statistical analyses.

Results
The difference between early postoperative and late postoperative tunnel width was evaluated by the Paired samples t-test. Accordingly, tunnel enlargement was detected in a significant part of endobutton and transfixes cases; the cases with tunnel enlargement difference at and over 2 mm were accepted as tunnel widening and evaluated in consideration of standard deviation. In this case, tunnel enlargement differences of 8 cases presented minimal increase or presented no change in Endobutton CL whereas a significant enlargement of both femoral and tibial tunnel was seen in 7 cases and of femoral tunnel was seen only in 2 cases (Table 1). The largest width difference was found as 6 mm in the femoral tunnel, 4 mm in the tibial tunnel; the mean width difference of the tunnel was found as 3.8 mm and 2.6 mm in the femoral tunnel and tibial tunnel, respectively (average of the cases with significant tunnel widening). There was not any significant tunnel widening in 15 cases who had transfix technique; however, a significant enlargement was detected in both femoral and tibial tunnel in 14 cases, for femoral tunnel only in 3 cases and for tibial tunnel only in 1 case (Table 2). Accordingly, it was detected that femoral tunnel was dilated by 5 mm and tibial tunnel was dilated by 7 mm. The mean dilatation measure of femoral tunnel and tibial tunnel was 3.6 mm and 3.8 mm, respectively.

Consequently, significant tunnel enlargement was detected in 47% of the cases in endobutton CL reconstruction group, and in 51.5% of the cases in transfix screw technique group.

In Table 1, p<0.001 was detected in paired sample t-test with standard deviation of 20,598. A significant tunnel enlargement difference was detected with these findings. Same p-value was found for Table 2, below with standard deviation of 178,895.

In Tables 3 and 4 below, 63% of the cases with femoral tunnels on Harner’s quadrant 3 through transfix technique presented a femoral tunnel width difference over 2 mm; however, such rate for the cases with the tunnels on Harner’s quadrant 4 was 37%. It was investigated whether such tunnel width difference ratios were associated with Harner’s quadrant. The Mann-Whitney U test was applied for this. The p-value is >0.005 in this test and there was not

| Table 1. Distribution of the cases with tunnel enlargement over 2 mm in endobutton technique |
|-----------------------------------------------|
| **Endobutton CL**                              |
| **Amount of femoral tunnel enlargement**       |
| **n=9**                                        |
| 2 mm                                          |
| 2.5 mm                                        |
| 3 mm                                          |
| 3.5 mm                                        |
| 4 mm                                          |
| 4.5 mm                                        |
| 5 mm                                          |
| 6 mm                                          |
| **Amount of tibial tunnel enlargement**        |
| **n=7**                                        |
| 2 mm                                          |
| 2.5 mm                                        |
| 3 mm                                          |
| 3.5 mm                                        |
| 4 mm                                          |
| 4.5 mm                                        |
| 5 mm                                          |
| 6 mm                                          |

| CL: Continuous loop |

| Table 2. Distribution of the cases with tunnel enlargement over 2 mm in transfix screw technique |
|-----------------------------------------------|
| **Transfix technique**                        |
| **Amount of femoral tunnel enlargement**      |
| **n=17**                                      |
| 2 mm                                          |
| 2.5 mm                                        |
| 3 mm                                          |
| 4 mm                                          |
| 4.5 mm                                        |
| 5 mm                                          |
| **Amount of tibial tunnel enlargement**       |
| **n=15**                                      |
| 2 mm                                          |
| 2.5 mm                                        |
| 3 mm                                          |
| 4 mm                                          |
| 4.5 mm                                        |
| 5 mm                                          |

| Table 3. Distribution of femoral tunnel width difference over 2 mm according to Harner’s quadrant in transfix screw technique |
|-----------------------------------------------|
| **Transfix technique (n=17)**                 |
| **Amount of femoral tunnel enlargement**      |
| **Harner quadrant 2**                         |
| **Harner quadrant 3**                         |
| **Harner quadrant 4**                         |
| 2 mm                                          |
| 2.5 mm                                        |
| 3 mm                                          |
| 4 mm                                          |
| 4.5 mm                                        |
| 5 mm                                          |

| Table 4. Distribution of the cases without significant tunnel widening according to Harner’s quadrants in transfix screw technique |
|-----------------------------------------------|
| **Transfix technique (n=16)**                 |
| **Amount of femoral tunnel enlargement less than 2 mm or absent** |
| **Harner quadrant 3**                         |
| **Harner quadrant 4**                         |
| 7                                             |
| 9                                             |

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any connection between Harner's quadrant and tunnel enlargement.

HSSKS scores of the patients with femoral tunnel width difference at and over 2 mm through transfix technique were found 90.2 whereas such score was 91.1 in the cases with none or minimal femoral tunnel width difference (Table 5 and 6). The p>0.005 value detected by the Mann-Whitney U test meant that this was not reflected to the clinical presentation. There was not any significant difference in score comparison of the cases with femoral tunnel width difference at and over 2 mm (Table 7) and in the cases with none or minimal tunnel width (Table 8) (p>0.005).

Postoperative rehabilitation period was similar in both groups; HSSKS scores of the cases who underwent transfix and endobutton techniques were compared (Table 9 and 10). The comparison was performed through the Mann-Whitney U test. The p>0.05 meant that there was not any clinically significant difference between two groups.

Discussion

L’insalata et al. (5) detected in their study conducted on ACL reconstructions through hamstring tendons that tunnel enlargement was more common than those performed by using patellar tendon graft. However, they did not explain that this was clinically meaningful. Similarly, Clatworthy et al. (6) detected in a study (in reconstructions on hamstring tendons) that the most enlargement of tunnel was in those using bioabsorbable screw, which was followed by metal interference screw, Bone Mulch screw and Endobutton CL. Clatworthy et al. (6) demonstrated in the aforesaid study that femoral tunnel enlargement could not be explained

Table 5. HSSKS distribution scores of the cases with femoral tunnel enlargement at and over 2 mm in transfix screw technique

| Transfix technique (n=17) | Amount of femoral tunnel enlargement | HSSKS | 81-85 point | 86-90 point | 91-95 point | 96-100 point |
|------------------------|-------------------------------|-------|-------------|-------------|-------------|-------------|
| 2 mm                   | -                             | 1     | 1           | -           | 2           | 2           |
| 2.5 mm                 | -                             | -     | 1           | -           | -           | -           |
| 3 mm                   | -                             | 2     | 2           | 1           | -           | -           |
| 4 mm                   | -                             | -     | 2           | 1           | -           | -           |
| 4.5 mm                 | -                             | -     | 1           | -           | -           | -           |
| 5 mm                   | 1                             | 2     | 1           | -           | -           | -           |

HSSKS: Hospital for Special Surgery Knee score

Table 6. HSSKS distribution scores of the cases without femoral tunnel widening at and below 2 mm in transfix screw technique

| Transfix technique | Amount of femoral tunnel enlargement minimal or absent | HSSKS | 80-85 | 86-90 | 91-95 | 96-100 |
|--------------------|-------------------------------------------------------|-------|-------|-------|-------|-------|
| 2                  | 5                                                     | 6     | 3     |       |       |       |

HSSKS: Hospital for Special Surgery Knee score

Table 7. HSSKS distribution scores of the cases with femoral tunnel widening at and over 2 mm in endobutton technique

| Endobutton CL (n=9) | Amount of femoral tunnel enlargement | HSSKS |
|---------------------|--------------------------------------|-------|
| 2 mm                | 1                                     | 1     |
| 3 mm                | 1                                     | 1     |
| 3.5 mm              | 2                                     | 2     |
| 4.5 mm              | 1                                     | 1     |
| 5 mm                | 1                                     | 1     |
| 6 mm                | -                                     | -     |

HSSKS: Hospital for Special Surgery Knee score, CL: Continuous loop

Table 8. HSSKS distribution scores of the cases without femoral tunnel widening at and below 2 mm in endobutton technique

| Endobutton CL (n=8) | Amount of femoral tunnel enlargement minimal or absent | HSSKS |
|---------------------|-------------------------------------------------------|-------|
| 1                   | 1                                                     | 1     |
| 3                   | 1                                                     | 3     |
| 6                   | -                                                     | -     |

HSSKS: Hospital for Special Surgery Knee score, CL: Continuous loop

Table 9. Distribution of HSSKS scores in the cases operated with transfix screw technique

| Transfix technique | HSSKS points |
|--------------------|--------------|
| 70-80              | 1            |
| 81-85              | 3            |
| 86-90              | 10           |
| 91-96              | 14           |
| 96-100             | 5            |

HSSKS: Hospital for Special Surgery Knee score

Table 10. Distribution of HSSKS scores in the cases operated with Endobutton technique

| Endobutton technique | HSSKS points |
|----------------------|--------------|
| 70-80                | 1            |
| 81-85                | 2            |
| 86-90                | 5            |
| 91-96                | 6            |
| 96-100               | 3            |

HSSKS: Hospital for Special Surgery Knee score
by “bunge-cord” effect in the cases in which Endobutton CL was used (6). The findings obtained in the present study were consistent with those obtained by Clatworthy et al. (6) detection of similar results in tunnel enlargement ratios of our cases both in Transfix and Endobutton CL techniques appears to prove that femoral tunnel enlargement by 65% of former tunnel diameter is due to tight rope effect. Because, tunnel enlargement occurs by 55% of former tunnel diameter in Transfix technique.

Moreover, the tibial tunnel was fixed by 1 staple and 1 bioabsorbable screw in majority of the cases with Transfix technique. However, double staples or washer were used in our Endobutton CL cases. This allowed us to compare tibial tunnel enlargement in both cases. The outcomes that we obtained were interesting because, some tibial tunnel enlargement quantity exceeded femoral tunnel width in Transfix screw technique. The mean tibial tunnel enlargement quantity was 2.6 mm in endobutton (calculated from those with significant tunnel enlargement), and 3.8 mm in Transfix screw technique. This was also consistent with the study conducted by Clatworthy et al. (6) However, tibial tunnel did not expand much although bioabsorbable screw was used in the cases without femoral tunnel enlargement.

Does tunnel enlargement make any sense for the patients? If it does, what was the extent of enlargement to increase the instability? Ayala-Majias et al. (7) selected a retrospective cohort of 30 patients undergoing ACL reconstruction with double semitendinosus plus double gracilis with longer than 10 -year follow-up to evaluate the relationship between tunnel position and widening and long term clinical results. They found that tibial tunnels widened more than femoral tunnels and tibial tunnel dilation was associated with long term degenerative changes but no with final knee instability (7). Nebelung et al. (8) evaluated 29 knees with a minimum follow-up 2 years after ACL reconstruction with endobutton technique. They have found no correlation between enlargement of the tunnel and the International Knee Documentation Committee score or the residual joint instability (8). Çınar et al. (9) investigated the effects of anatomic and nonanatomic tunnel fixations on femoral tunnel widening and clinical results in ACL reconstruction with hamstring tendon graft. They found that there was marked and excessive tunnel enlargement in anatomic and non-anatomic tunnel fixations. They demonstrated that there was no relationship between tunnel widening and clinical results and ligament laxity (9). We could not find a relationship between tunnel enlargement and clinical outcomes in the both groups too; however, we detected that clinical status was moderate in the cases with tunnel widening by 50% and more of former tunnel diameter and HSSKS scores accumulated around 86 to 88. Majority of them were without instability; however, it was observed that they abstained from previous sports that they used to make before the surgery and they perform different sports. Furthermore, it should be stressed out that tunnel enlargement exceeding 50% of former enlargement diameter was 16% of our cases only.

Endobutton and Transfix screw are the materials providing extraarticular femoral fixation. The most superior characteristics include their resistance, strength against loading during femoral fixation with the strongest scraping forces (10-12). Another superior feature is not leading to posterior cortex wall fracture during fixation. Endobutton also has two other superior characteristics. One of them is serving as a material used for both hamstring tendons and patellar tendon bone graft, and the other is providing external rotation to the graft during tibial fixation of the graft. Despite such additional superior characteristics of Endobutton, usage was not common among surgeons in the past. Two settled views caused this. One view was that Endobutton causes tunnel enlargement more than transfix due to tight rope effect; and it was shown that this was not correct. The second view was the desire to keep Endobutton as a priceless option for revision ligament surgery in the future. Femoral tunnel fixations were mostly used to be done inside the tunnel for that reason, and fixation failure was detected frequently (13). Furthermore, removal of femoral tunnel screws located intraarticularly is difficult and results with significant tunnel dilatation when removed (14). Anatomic ACL reconstruction is done nowadays and transtibial technique has almost been abandoned. Endobutton fixation material is commonly used to fixate femoral tunnel. Revision of ACL becomes difficult due to current femoral tunnel widening in the patients who had anatomic ACL reconstruction before with accurate femoral tunnel location. At this point, we believe that dominating transtibial technique is important. Because, the new femoral tunnel to be opened inside former tibial tunnel by keeping the frontal tibial angle at 60 degrees in average would be closer to anatomic location and longer than former tunnel. It is reported that if failure to thrive angle is over 75 degrees, it increases anterior laxity and causes loss of flexion (15). Furthermore, opening new femoral tunnel in transtibial technique allows an increase in disintegration probably due to the dilated tibial tunnel. This would enable to open the femoral tunnel more anatomically. Femoral tunnel grafting
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may not be needed. We observe better results of a patient whom we have performed ACL reconstruction 20 years ago and still follow up (Figure 4 and 5). In the AP/lateral X-rays of the knee, femoral and tibial tunnels appear not to be enlarged. The knee examination revealed that Lachman 1 was positive, and the patient did not have any problem in the daily life. Furthermore, one of the noticeable points is the absence of osteoarthritis complaints.

Conclusion

Comparison of both techniques in the present study revealed no difference radiologically and for tunnel dilatation; and both fixation materials may be easily used if transtibial ACL revision would be done.

Ethics

Ethics Committee Approval: This retrospective study was conducted on 50 patients who had ACL reconstruction in SCI Göztepe Training and Research Hospital between September, 1999 and March, 2003.

Informed Consent: The study was conducted with the consent of all patients.

Peer-review: Externally peer-reviewed.

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References

1. Panni AS, Milano G, Tartarone M, Demontis A, Fabbriciani C. Clinical and radiographic results of ACL reconstruction: a 5- to 7-year follow-up study of outside-in versus inside-out reconstruction techniques. Knee Surg Sports Traumatol Arthrosc 2001;9(2):77-85.

2. Katz JW, Fingeroth RJ. The diagnostic accuracy of ruptures of the Anterior Cruciate Ligament comparing the Lachman test, the Anterior drawer sign, and Pivot Shift test in acute and chronic knee injuries. Am J Sports Med 1986;14(1):88-91.

3. Wilson TC, Kantaras A, Atay A, Johnson DL. Tunnel enlargement after anterior cruciate ligament surgery. Am J Sports Med 2004;32(2):543-549.

4. Höher J, Müller HD, Fu FH, Harner CD. Bone tunnel enlargement after anterior cruciate ligament reconstruction: fact or fiction? Knee Surg Sports Traumatol Arthrosc 1998;6(4):231-240.

5. L’Insalata JC, Klatt B, Fu FH, Hama CD. Tunnel expansion following anterior cruciate ligament reconstruction: a comprasion of hamstring and patellar autografts. Knee Surg Sports Traumatol Arthrosc 1997;5(4):234-238.

6. Clatworthy MG, Annear P, Bulow JU, Bartlett RJ. Tunnel widening in anterior cruciate ligament reconstruction: a prespective evaluation of hamstring and patella tendon grafts. Knee Surg Sports Traumatol Arthrosc 1999;7(3):138-145.

7. Ayala-Majias J, Garcia-Gonzalez B, Alcocer-Perez-Expana L, Berjano P, Villafane J. Relationship Between Widening and Position of the Tunnels and Clinical Results of Anterior Cruciate Ligament Reconstruction to Knee Osteoarthritis: 30 Patients at a Minimum Follow-Up 10 Years. J Knee Surg 2017;30(6):501-508.

8. Nebelung W, Becker R, Merkel M, Röpke M. Bone tunnel enlargement after anterior cruciate ligament reconstruction with semitendinosus tendon using endobutton fixation on the femoral side. Arthroscopy 1998;14(8):810-815.

9. Çınar BM, Akpınar S, Hersekli MA, Uysal M, Cesur N, Pourbagher A, et al. The effects of two different fixation methods on femoral bone tunnel enlargement and clinical results in anterior cruciate ligament reconstruction with hamstring tendon graft. Acta Orthopaedica et Traumatologica Turcica 2009;43(6):515-521.

10. Brand. Jr, Weiler A, Caborn DNM, Brown. CHJr, Johnson DL. Graft Fixation in Cruciate Ligament Reconstruction. Am J Sport Med 2000;28:761-774.
11. Vander Reis WL, Deffner KT, Rosenberg TD. Comparison of hamstring fixation devices under cyclic and other loading. AOSSM, Specialty Day. Orlando FL, 2000, Abstract Book, p:88-89.

12. Yosmaoğlu HB, Baltacı G, Kaya D, Özer H, Atay A. Comparison of functional outcomes of two anterior cruciate ligament reconstruction methods with hamstring tendon graft. Acta Orthop Traumatol Turc 2011;45(4):240-247.

13. Derez DJ, DeLee J, Holden JP, Arnoczky S, Noyes FR, Roberts TS. Anterior cruciate ligament reconstruction using bone patellar tendon bone allografts. A biological and biomechanical evaluation in grafts. Am J Sports Med 1991;19(3):256-263.

14. Reha Tandoğan N. Ön Çapraz Bağ Cerrahisi. Spor Yaralanmaları, Artroskopi ve Diz Cerrahisi Derneği Yayınları. Ankara: Sim Matbaası, 2002.

15. Howell SM, Gittins ME, Gottlieb JE, Traina SM, Zoellnor TM. The relation- ship between the single of the tibial tunnel in the coronal plane and loss of flexion and anterior laxity after anterior cruciate ligament reconstruction. Am J Sports Med 2001;29(5):567-574.