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A Prospective study on the functional outcome following arthroscopic ACL reconstruction with the femoral interference screw placed through the PT (Patellar Tendon) portal and the AM (Antero-Medial) portal

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Abstract
The knee joint is the most commonly injured of all joints and the anterior cruciate ligament is the most commonly injured ligament. Arthroscopic reconstruction of torn ACL has become the gold standard in treating ACL tears. The primary aim of this prospective randomized comparative study was to investigate whether an interference screw placed through the PT portal shows less divergence as compared with a screw placed through the AM portal.

Materials and Methods: This is a randomized controlled study. 24 patients have been included in the study. Femoral tunnel-interference screw divergence will be measured on postoperative digital lateral X-rays. Ha's method will be used to grade divergence. The radiologist was blinded for the technique used (AM or PT portal).The clinical outcome will be assessed by postoperative intervention knee documentation committee grading (IKDC) and Lysholm score at two year follow up. The study shall be of two and half years duration with effect from May 2015 to October 2017.

Results: In our series of 24 patients, mean age was 30.6 years.With respect to the IKDC scoring, 95.83 % patients had normal or nearly normal outcome and 4.16% had abnormal outcomes. We had 95.83 % excellent and good results with respect to Lysholm score, 4.16 % had fair outcome and we did not have any poor outcomes. In our study we had 12 patients in each group (AM and PT). The mean divergence in group 1 (AM portal) is 13.15º. Mean angle of divergence in group 2 (PT portal) is 7.24º

Conclusion: Arthroscopic ACL reconstruction using bone-patellar tendon-bone autograft provides a stable knee with minimal complications. The short term results of femoral interference screw placement through the patellar tendon portal for arthroscopic ACL reconstruction using bone patellar tendon bone graft are encouraging with minimal screw divergence with a good clinical outcome.

Keywords: Interference screw, screw divergence, Anteromedial portal, Patellar tendon portal

Introduction

The knee joint is the most commonly injured of all joints and the anterior cruciate ligament is the most commonly injured ligament [1]. The anterior cruciate ligament forms the pivot in the functional congruence and stability of the knee in association with other ligaments, capsule, muscles and bone [2, 3]. The anterior cruciate ligament is the primary stabilizer of the knee and prevents the knee against anterior translation [4]. It is also important in counteracting rotational and valgus stress [5]. ACL tears have been termed as the "beginning of the end of the knee". Whilst some patients can be managed nonoperatively with intense physiotherapy, bracing and modification of activity, severe symptoms require reconstruction. Arthroscopic reconstruction of torn ACL has become the gold standard in treating ACL tears [10]. The surgical reconstruction of the anterior cruciate ligament with Bone-Patellar tendon-Bone autograft represents an attempt to re-establish knee kinematics. It has the added advantage of bone to bone healing and it does not sacrifice the knee stabilizers [11].Various factors affect the pullout strength of the graft: *bone block size, quality of bone, gap between bone block and tunnel, screw diameter and length and the angle between screw and bone block (parallel or divergent)* [30-36]. Parallel placement of the screw with respect to femoral and tibial tunnel is desired as it is one of the factors which affect the pullout strength of the graft [32].

Biomechanical and clinical ramifications of a divergent interference screw in the bone tunnel (tibial or femoral) is now well established and is one of the key factors in the success of the B-PT-B graft [30-32]. It is easy to place the interference screw parallel to the bone block in the tibial tunnel as direction of drilling and placement of the interference screw are same. Commonly, the interference screw in a transtibially drilled femoral tunnel is usually placed through the anteromedial (AM) portal or accessory AM portal over a guide wire. However, this is not-in-line with the transtibially drilled femoral tunnel and can lead to screw divergence. If the divergence is more than 15º between interference screw and bone block, the pullout strength of the graft decreases sharply affecting the graft-tunnel healing, pullout strength, and the clinical outcome [31, 32, 37-40].

Materials and Methods

In patients who are undergoing arthroscopic anterior cruciate ligament reconstruction using bone-patellar tendon-bone graft, the femoral tunnel fixation was done by either of the following techniques. One is through Anteromedial AM portal (group 1) and other through Patellar Tendon PT portal – donor defect (group 2). Femoral tunnel-interference screw divergence will be measured on postoperative digital lateral X-rays. Ha's method will be used to grade divergence. Angle was measured in degrees between the longitudinal axis of tunnel and interference screw by an experienced radiologist on two separate occasions. The radiologist was blinded for the technique used (AM or PT portal).

Screw divergence was classified into four grades, as described by Kwon Ick Ha *et al*. [41] Grade 1 (no divergence) were patients with 0º to 5º divergence; grade 2 were 5º to 10º (Mild); grade 3 were 10º to 15º (moderate); and grade 4 were greater than 15 º (severe).

The clinical outcome will be assessed by postoperative intervention knee documentation committee grading (IKDC) and Lysholm score at two year follow up.

The study shall be of two and half years duration with effect from May 2015 to October 2017.

Operative Procedure

Under spinal or epidural anaesthesia the patient was put supine in the fracture table with the affected leg in hanging positon and the other leg in lithotomy position. The knee is examined for ligament injury using Lachman test, anterior drawer test, pivot shift test, valgus and varus stress test and posterior drawer test. After applying tourniquet the knee was extended over leg holder. Parts were cleaned and draped and a diagnostic arthroscopy was performed using standard anterolateral and anteromedial portals. The diagnosis of ACL tear confirmed arthroscopically and associated chondral lesions and meniscal tears diagnosed and treated. All patients underwent single incision ACL reconstruction using B-PT-B graft.

The middle third of the patellar tendon measured approximately 10 mm and harvested along with patellar and tibial bone plugs upto 25 mm long. The bone plugs are trimmed to the desired width (8mm - 11 mm). The width checked using appropriate sizer templates. The graft edges are smoothened and sutures passed through the drill holes. Notchplasty was done using a specialized curette and automated shaver. The tibial tunnel is made using the 'TIBIAL JIG'. The angle of the guide is usually adjusted with the calculation 'N + 10' where N stands for the length of the patellar tendon. The tibial tunnel was prepared by serial drilling from 6 to 9 mm cannulated reamers over a guide wire exiting 6 mm anterior to the anterior fibers of posterior cruciate ligament, just medial to medial tibial spine in the posterior footprint of torn ACL fibers.

With the knee at 80 to 90º of flexion, femoral tunnel was drilled over a guide wire which was kept 7 mm anterior to posterior edge of lateral femoral condyle at 10:30 o'clock in right knee and 1:30 o'clock in left knee using a femoral offset of 6 mm. Bicortical drilling was done with 4-mm cannulated reamer. Then, 30 mm long femoral tunnel was drilled serially with 7- to 9-mm cannulated reamers. The posterior cortex is checked for any breach of the back wall.

Graft Passage: The sutures are passed through the eye of the Beath pin and the proximal end of the pin is pulled to pass the graft through the tibial and femoral tunnel from bottom to the top. The cancellous portion of graft was facing anterolateral. Care is taken that no bone is allowed to protrude into the joint cavity at both tibial and femoral ends

Graft Fixation: Knee was flexed to 110 º and a guide wire advanced into the notched portion of tunnel to minimize divergence through the selected portal, i.e., AM (group 1) or PT (group 2) portal (through the donor defect). To achieve graft fixation in femoral tunnel, titanium interference screw of appropriate length and diameter was inserted over the guide wire using the selected portal (according to randomization) into the femoral tunnel. Care is taken for the screw not to protrude into articular area.

Again, guide wire was kept parallel to graft in tibial tunnel and graft was fixed with interference screw keeping the knee at 30º flexion with force directed posteriorly onto the shin of tibia. Interference screws are placed at the cancellous side of the bone plug in tibial tunnel with the graft sutures pulled firmly under tension.

After the ACL reconstruction, Lachman and Pivot shift test were performed to assess the adequacy of fixation.

Post-Op Rehabilitation

Rehabilitation was started on the day after surgery under the direct supervision of the surgeon. Drain removed at 24-48 hours. The knee was immobilized in knee brace. The accelerated rehabilitation program includes the following.

Closed chain exercises started on day one. Active SLR and static quadriceps strengthening exercises were started. Two crutch ambulation was allowed with the knee immobilized, with weight bearing as tolerated. Sutures were removed on the 14th post op day. Intermittent passive range of motion was encouraged. Weight bearing was allowed with knee brace up to 6 weeks. Active flexion was started at the end of 6 weeks. Patient was allowed active and active-assisted knee mobilization and gradual quadriceps strengthening exercises. Crutches were discontinued when quadriceps control is acquired. Physiotherapy is continued up to 9 months post-surgery.

Time	Motion	Muscles Training
Phase - I Preoperative	Aim to prevent muscle atrophy	Good quadriceps setting.

	Prepare patient for procedure	Heel slides/ SLR Normal gait pattern emphasized
Stage - II Upto 2 weeks	Aim to decrease pain & swelling Starts on day of surgery	Knee immobilized Quadriceps exercise Foot ankle pump
Stage III 2 - 6 weeks	Emphasis on increasing ROM Increasing weight bearing	Brace continued Full weight bearing No active flexion
Stage IV After 6 weeks	Aim in improving muscular control and proprioception	Closed chain Kinetic exercise Active knee flexion

Evaluation

Postoperatively X rays (Standard Antero-posterior and Lateral views) were taken on the operated limb. The tunnel positioning and screw placement were documented. All patients were reviewed periodically at 6 weeks, 3 months, 6 months and 1 year for assessment.

The patients were evaluated using the International Knee Documentation 2000 Score (IKDC) and Lysholm & Gillquist Knee Scoring Scale.

Result Analysis

All the 24 patients were available for follow-up and they were followed up every month during the first 4 months and every 2 months during the first year. The minimum follow-up was 6 months and maximum was 25 months, mean follow-up being 15.75 months. Twelve patients underwent femoral tunnel fixation by titanium interference screw through AM portal (group 1) and other 12 patients through PT portal (group 2).

The mean age was 30.6 years. It ranged from 19 years to 47 years. 45.83 % of the cases were between 21-30 years.There were 20 males and 4 females in this study. There were 2 females and 10 males in each group. 12 out of 24 cases were because of sports injury. Of the 24 patients, right knee was affected in 14 cases and in 10 cases left knee was involved. Of these 6 left knees and 6 right knees, the femoral interference screw was placed through the patellar tendon portal (PT). 4 left knees and 8 right knees, the femoral interference screw was placed through the anteromedial portal (AM). Of the 24 patients, majority of patients i.e., 10 patients had interval of >3months to 6 months, between the date of injury and date of surgery. Of the 10 patients 4 patients were in group 1 and 6 patients in group 2. Overall 13 patients had knee pain, 6 patients had instability, 1 patient had locking episodes, and 4 patients had both knee pain and instability. Of the 13 patients, who had knee pain 7 patients were in group 1 and 6 patients in group 2.

All the patients at the end of 1 year follow up were functionally evaluated based on IKDC SCORE. Of the 24 patients, 15 patients had normal outcome, 8 patients had nearly normal outcome and 1 patient had abnormal outcome. Of the 15 normal outcomes, 6 patients belonged to group 1 (AM) and 9 patients belonged to group 2 (PT). Of the 8 nearly normal outcomes, 5 patients belonged to group 1 (AM) and 3 patients belonged to group 2 (PT). 1 patient who had an abnormal outcome belonged to group 1 (AM) attributed to poor preoperative IKDC score.Of the patients taken up for the study 15 patients had improved by one grade and 9 patients had improved by 2 grades.

Table 1: Ikdc grading of knees at two-year follow-up in two different groups with respect to the grade of interference screw-tunnel divergence

	Ha grade							
	G1		**G2**		**G3**		**G4**	
IKDC SCORE	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**
AM (no. of cases)	0	0	2	1	4	2	0	2
PT (no. of cases)	2	0	6	2	1	1	0	0

We had 75% of the patients in the AM portal group with divergence in either grade 3 or 4 category, where as in PT portal group, 83.33 % of the patients were in grade 1 or 2 category. Chi square test applied between the two groups was statistically significant (P<0.0001).

Table 2: Grades of interference screw-femoral tunnel divergence between two groups

	Grade 1 (0º -5º)	**Grade 2 (5º-10º)**	**Grade 3 (10º-15º)**	**Grade 4 (>15º)**
Group 1(AM) (% within portal)	0	(3) 25 %	(7) 58.33%	(2) 16.67 %
Group 2 (PT) (% within portal)	(2) 16.67 %	(8) 66.67 %	(2) 16.67 %	0

Table 3: lysholm score charted groupwise

	No. of Cases	**Percentage**
Excellent	15	62.50 %
Good	8	33.33 %
Fair	1	4.16 %
Poor	0	0 %

The Lysholm and Gillquist knee scoring scale was also used to evaluate the functional status of our patients. We had 15 patients with Excellent outcome, 7 patients with good outcome and 1 patient had a fair outcome.

Of the 15 patients with excellent outcomes, 6 patients belong to group 1 (AM) and 9 patients belong to group 2 (PT). Of 8 patients with good outcome, 5 patients belong to group 1 (AM) and 3 patients belong to group 2 (PT). The fair outcome belonged to group 1 (AM). Both groups had average postoperative Lysholm score of 91.6 (group 1) and 95.4 (group 2).

Screw Divergence

Table 4: Mean Angle of interference screw- femoral tunnel divergence between two groups

	Mean angle of tunnel screw divergence (degrees)	**Percentage Of patients**
Group 1 anteromedial portal n=12	13.15º	50 %
Group 2 patellar tendon portal n=12	7.24º	50 %

The mean tunnel-screw divergence in sagittal plane through AM portal was 13.15º and through PT portal through donor defect was 7.24º.

Discussion

Over the past several decades, development in arthroscopic techniques and improvement in technology and research have allowed anterior cruciate reconstruction to become one of the most successful surgical techniques in sports medicine. At present the most commonly used grafts for ACL reconstructions are bone-patellar tendon-bone autograft and hamstring tendon grafts. The central one third of the bone-patellar tendon-bone graft was used because of its excellent biomechanical properties. It is the strongest of the immediately available substitute. The graft can be placed accurately during the surgery for it to act isometrically both in its location and tension. Bone to bone healing is more secure and rapid when compared to other grafts. It does not sacrifice the knee stabilizers. The bone-patellar tendon-bone graft is time tested and has lesser complications and less significant morbidity.

We have made the following observations from our study. Males sustained this injury more than the females, the ratio being 5:1. Sports injury are the most common mode of injury and it accounted for about 50% of the cases. Right knee was involved in more number of cases i.e., in about 58.33% cases. About 11 out of 24 cases were between 21 - 30 years i.e, (45.83 %). The mean age is 30.6 years. Majority of patients i.e., 10 patients had interval of more than 3months to 6 months, between the date of injury and date of surgery. Overall 13 patients had knee pain, 6 patients had instability, 1 patient had locking episodes, and 4 patients had both knee pain and instability. Of the 24 patients, 15 patients had normal outcomes, 8 patients had nearly normal outcome and 1 patient had abnormal outcome. We had 75% of the patients in the AM portal group with divergence in either grade 3 or 4 category, where as in PT portal group, 83.33 % of the patients were in grade 1 or 2 category. Of the 15 patients with excellent outcomes, 6 patients belong to group 1 (AM) and 9 patients belong to group 2 (PT). Of 8 patients with good outcome, 5 patients belong to group 1 (AM) and 3 patients belong to group 2 (PT).Both groups had average postoperative Lysholm score of 91.6 (group 1) and 95.4 (group 2).The mean tunnel-screw divergence in sagittal plane through AM portal was 13.15^{o}and through PT portal through donor defect was 7.24^{o}. 12 patients out of our 24 patients had associated chondral lesions. Meniscal injuries were present in 13 patients. 9 patients had medial meniscal tear. 4 patients had lateral meniscal tear.

Conclusion

Anterior cruciate ligament injuries are common in younger age group individuals. Males are more prone for anterior cruciate ligament injuries. Sports injuries are the commonest cause for anterior cruciate ligament injuries. Associated meniscal and chondral lesions increase with duration of the injury. Arthroscopic anterior cruciate ligament reconstruction with bone- patellar tendon-bone graft is an excellent treatment option for anterior cruciate ligament deficient knees.

Meniscal injuries do not affect the final outcome in anterior cruciate ligament reconstructed patients in short term follow up. Arthroscopic ACL reconstruction using bone-patellar tendon-bone autograft provides a stable knee with minimal complications. Arthroscopic anterior cruciate ligament reconstruction reduces postoperative morbidity and enables early rehabilitation.

Femoral interference screw placement through the PT defect provides significantly less screw divergence as compared with screw placement through the AM portal.

The limitation of this study is that only sagittal plane divergence has been evaluated. It is difficult to accurately outline the femoral tunnel in the coronal plane in AP view of X-ray. However, a randomized study with larger sample size with long follow up is desired to study the relation between multiplanar divergence (using computed tomography scan) and clinical outcome using these two portals.

The short term results of femoral interference screw placement through the patellar tendon portal for arthroscopic ACL reconstruction using bone patellar tendon bone graft are encouraging with minimal screw divergence with a good clinical outcome. There is a clear need for prospective long term follow up studies.

References

1. Butler DL, Noyes FR, Grood ES. Ligamentous restraints to anterior- posterior drawer in human knee. A biomechanical study. J Bone Joint Surg Am. 1980; 62:259- 70.
2. Haimes JL, Wroble RR, Grood ES, Noyes FR. Role of medial structures in the intact and anterior cruciate ligament deficient knee. Limits of motion in the human knee. Am J Sports Med 1994, 22:402-409.
3. Markolf KL, Wascher DC, Finerman GAM. Direct invitro, measurement of forces in the cruciate ligament. Part II: The effect of section of the posterolateral structures. J Bone and Joint Surg Am 1993; 75-A:387-394.
4. Frank CB, Jackson DW. Current concepts review. The science of reconstruction of the anterior cruciate ligament. J Bone and Joint Surg Am. 1997; 79:1556-76.
5. Kanamori A, Woo SL, Ma CB, Zeminski J, Rudy TW, Li G, *et al*. The forces in the anterior cruciate ligament and knee kinematics during a simulated pivot shift test: a human cadaveric study using robotic technology. Arthroscopy 2000; 16:888-9.
6. Del Pizzo W, Norwood LA, Kerlan RK, Jobe FW, Carter VS, Blazing ME *et al*. Analysis of 100 patients with anterolateral rotatory instability of the knee. Clin Orthop 1977; 122:178180.
7. Satku K, Kumar VP, Ngoi SS. ACL injuries. To counsel or to operate? J Bone Joint Surg Br. 1986; 68:458-61
8. Curl WW, Krome J, Gordon ES. Cartilage injuries: A review of 51,516 knee arthroscopies. Arthroscopy. 1997; 13(4):456-60.
9. Howe, Johnson, Kaplan. ACL reconstruction using quadriceps patellar tendon graft. Part I. Long term follow up. Am J of Sports Med. 1991; 19:447-57.
10. Fu FH, Bennett CH, Ma CB. Current trends in anterior cruciate ligament reconstruction: Operative procedures and clinical correlation. Am J of Sports Med. 2000; 28:124-130.
11. Aune AK, Holm I, Riseberg MA, Jensen HK, Steen H. Four strand hamstring tendon autograft compared with patellar tendon bone autograft for anterior cruciate ligament reconstruction: A randomized study with two year follow up. Am J Sports Med. 2001; 29:722-728.
12. Delay BS, Smolinski RJ, Wind WM, Bowman DS. Current practices and opinions in ACL reconstruction and rehabilitation: Results of a survey of the American Orthopaedic Society for Sports Medicine. Am J Knee Surg. 2001; 14:85-91.
13. Mirza F, Mai DD, Kirkley A, Fowler PJ, Amendola A. Management of injuries to the anterior cruciate ligament: Results of a survey of orthopaedic surgeons in Canada.

Clin J Sport Med. 2000; 10:85-8.
14. Francis A, Thomas RD, McGregor A. Anterior cruciate ligament rupture: Reconstruction surgery and rehabilitation: a nation-wide survey of current practice. Knee 2001; 8:13-8.
15. Rodeo SA, Arnoczky SP, Torzilli PA, Hidaka C, Warren RF. Tendon healing in a bone tunnel. J Bone Joint Surg Am 1993; 75:1795-803
16. Butler DL. Evaluation of fixation methods in cruciate ligament replacement. Instr Course Lect. 1987; 36:173-8.
17. Markolf KL, Burchfield DM, Shapiro MM, Cha CW, Finerman GA, Slauterbeck JL. Biomechancial consequences of replacement of the anterior cruciate ligament with a patellar ligament allograft. Part II: forces in the graft compared with forces in the intact ligament. J Bone Joint Surg Am. 1996; 78:1728-34.
18. Hardin GT, Bach BR Jr, Bush-Joseph CA, Farr J. Endoscopic single incision ACL reconstruction using patellar tendon autograft: Surgical technique. 1992 [classical article]. J Knee Surg 2003; 16:135-44.
19. Engebretsen L, Benum P, Fasting O, Mølster A, Strand T. A prospective randomized study of three surgical techniques for treatment of acute ruptures of the anterior cruciate ligament. Am J Sports Med. 1990; 18:585-90.
20. Magen HE, Howell SM, Hull ML. Structural properties of six tibial fixation methods for anterior cruciate ligament soft tissue grafts. Am J Sports Med 1999; 27:35-43.
21. McCarroll JR, Rettig AC, Shelbourne KD. Anterior cruciate ligament injuries in the young athlete with open physes. Am J Sports Med. 1988; 16:44-7.
22. Shelbourne KD, Whitaker HJ, McCarroll JR, Rettig AC, Hirschman LD. Anterior cruciate ligament injury: evaluation of intraarticular reconstruction of acute tears without repair: Two to seven year follow-up of 155 athletes. Am J Sports Med. 1990; 18:484-8.
23. Noyes FR, Butler DL, Grood ES, Zernicke RF, Hefzy MS. Biomechanical analysis of human ligament grafts used in knee-ligament repairs and reconstructions. J Bone Joint Surg Am. 1984; 66:344-52.
24. Bach BR Jr. Arthroscopy assisted patellar tendon substitution for anterior cruciate ligament reconstruction. Am J Knee Surg. 1989; 2:3-20.
25. Bach BR Jr, Jones GT, Sweet FA, Hager CA. Arthroscopy assisted anterior cruciate ligament reconstruction using patellar tendon substitution: Two- to four-year follow-up results. Am J Sports Med. 1994; 22:758-67.
26. Harner CD, Marks PH, Fu FH, Irrgang JJ, Silby MB, Mengato R. Anterior cruciate ligament reconstruction: Endoscopic versus two-incision technique. Arthroscopy. 1994; 10:502-12.
27. Jackson DW, Reimann PR. Principles of arthroscopic anterior cruciate reconstruction. In: Jackson DW, Drez D editor. The anterior cruciate defcient knee: New concepts in ligament repair, St. Louis: Mosby; 1987, 237-85.
28. Marder RA, Raskind JR, Carroll M. Prospective evaluation of arthroscopically assisted anterior cruciate ligament reconstruction: Patellar tendon versus semitendinosus and gracilis tendons. Am J Sports Med. 1991; 19:478-84.
29. Rosenberg TD, Paulos LE, Abbott PJ Jr. Arthroscopic cruciate repair and reconstruction: An overview and description of technique. In: Feagin JA Jr editor. The crucial ligaments. New York: Churchill Livingstone. 1988, 409-24.
30. Kurosaka M, Yoshiya S, Andrish JT. A biomechanical comparison of different surgical techniques of graft fixation in anterior cruciate ligament reconstruction. Am J Sports Med. 1987; 15:225-9.
31. Fulkerson JP, Pierz K, Baltz M, Wright J, Nowak M, Post W *et al*. Potential problems in Kurosaka screw fixation of bone-tendon-bone graft transplants. Presented at Meeting of the American Orthopaedic Society for Sports Medicine, San Francisco, CA, 1993.
32. Johma NM, Raso VJ, Leung P. Effect of varying angles on the pullout strength of interference screw fixation. Arthroscopy. 1993; 9:580-3.
33. Matthews LS, Lawrence SJ, Yahiro MA, Sinclair MR. Fixation strengths of patellar tendon-bone grafts. Arthroscopy. 1993; 9:76-81.
34. Shapiro JD, Cohn BT, Jackson DW, Postak PD, Parker RD, Greenwald AS. The biomechanical effects of geometric configuration of bone-tendon-bone autografts in anterior cruciate ligament reconstruction. Arthroscopy. 1992; 8:453-8.
35. Daniel D, Akeson W, O'Conner J. Knee ligaments--Structure, function, injury and repair. New York, Raven Press. 1990, 25-9.
36. Brown CH Jr, Hecker AT, Hipp JA, Myers ER, Hayes WC. The biomechanics of interference screw fixation of patellar tendon anterior cruciate ligament grafts. Am J Sports Med. 1993; 21:880-6.
37. Fanelli GC, Desai BM, Cummings PD, Hanks GA, Kalenak A. Divergent alignment of the femoral interference screw in single incision endoscopic reconstruction of the anterior cruciate ligament. Contemp Orthop 1994; 28:21-5.
38. Lemos MJ, Jackson DW, Lee TQ, Simon TM. Assessment of initial fixation of endoscopic interference femoral screws with divergent and parallel placement. Arthroscopy. 1995; 11:37-41.
39. Pierz K, Baltz M, Fulkerson J. The effect of Kurosaka screw divergence on the holding strength of bone-tendon-bone grafts. Am J Sports Med. 1995; 23:332-5.
40. Matthews LS, Softer SR. Pitfalls in the use of interference screws for anterior cruciate ligament reconstruction: Brief report. Arthroscopy. 1989; 5:225-6.
41. Kwon-Ick Ha, Seung-Ho Kim, Jin-Hwan Ahn. The HAKI technique of femoral screw insertion. Technical note. Arthroscopy. 1999; 15:110-4.