

No Difference in Outcome of Anterior Cruciate Ligament Reconstruction with “Bone–patellar Tendon-bone versus Semitendinosus-gracilis Graft with Preserved Insertion:” A Randomized Clinical Trial

Abstract

Background: The type of graft for anterior cruciate ligament (ACL) reconstruction is still a topic of debate and there is still no clear consensus on the ideal graft for ACL reconstruction. **Purpose:** This study was conducted to compare the outcome of ACL reconstruction surgery between hamstring tendon graft and bone–patellar tendon-bone (BPTB) graft. **Materials and Methods:** One hundred and sixty professional athletes were enrolled in the study. They were divided into two groups by computerized randomization. In Group I, ACL reconstruction was done using BPTB graft, and in Group II, ACL reconstruction was done using semitendinosus gracilis graft with preserved tibial insertion (STGPI). Postoperatively, patients were assessed for knee stability, Lysholm score, and WOMAC score. **Results:** Mean KT-1000 side-to-side difference at 1 year was 2.31 ± 1.68 mm in BPTB cohort and 2.52 ± 1.6 mm in STGPI cohort ($P = 0.4$); and at 2 years, it was 1.98 ± 1.62 mm in BPTB cohort and 2.23 ± 1.6 mm in STGPI cohort ($P = 0.4$). Mean Lysholm score at 2 years was 96.1 ± 5.81 in STGPI cohort and 97.3 ± 4.62 in BPTB cohort ($P = 0.15$). Mean WOMAC score at 2 years was 3.3 ± 2.76 in STGPI cohort and 2.84 ± 2.21 in BPTB cohort ($P = 0.25$). Graft rupture rate was 3.75%; 3 patients in each group had graft rupture. Kneeling pain was present in 15% (12/80) of patients with BPTB graft whereas none of the patients in STGPI cohort had kneeling pain. **Conclusion:** There was no difference between two grafts in term of knee stability, visual analog scale score and functional outcome. However, hamstring tendon graft is associated with less donor site morbidity.

Keywords: Anterior cruciate ligament, bone–patellar tendon-bone, hamstring tendon graft

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Introduction

Anterior cruciate ligament (ACL) tear is a common injury among sportspersons. It is important to be pragmatic in addressing these injuries, especially in sportsmen, thereby avoiding the risk to their physical ability and competitive career.¹ With the increasing incidence of ACL tear in sportspersons optimal graft choice becomes an important topic of debate. However, despite the extensive research on this topic, so far there is no consensus on whether bone–patellar tendon-bone graft (BPTB) or doubled loop semitendinosus and gracilis graft (STG graft) is a superior graft.^{2,3} Some authors considered BPTB graft as the gold standard for ACL reconstruction due to its low level of laxity, high durability, higher incidence of return to sports, and appropriate size.⁴⁻⁶ However, on the other

side, it is criticized for its donor site morbidities such as anterior knee pain, patellar fracture, and quadriceps rupture.⁷ Due to the above-mentioned morbidities, the recent trend is shifting toward the hamstring tendon graft. The hamstring tendon graft does have its pros and cons such as its association with joint laxity,⁸ reduced hamstring strength,⁹ and higher graft rupture rate.¹⁰ However, most of the peer-reviewed articles showed satisfactory results with both the grafts.¹¹⁻¹⁷ In the previous study, it was observed that doubled loop STG graft with preserved tibial insertion (STGPI) was superior to free double looped STG graft in terms of knee stability and functional outcome.¹⁸ The purpose of this study was to compare the outcome of ACL reconstruction surgery between STGPI and BPTB graft. It was hypothesized that STGPI graft

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has a similar functional outcome with less donor site morbidities as compared to BPTB graft.

Materials and Methods

This was a level-I prospective randomized controlled study conducted from the year 2014 to 2019. This study was registered with the Clinical Trial Registry - India (CTRI/2016/01/006502). A total of 160 athletes, who sustained injury while playing different sports [Table 1], were enrolled in the study (SK) after the institutional ethical clearance. A well informed written consent was taken from each patient. Professional athletes, who were age and gender matched with age limit between 16 and 40 years, were included in this study. Athlete complaining of the instability of knee while playing and clinical examination suggestive of ACL tear was considered as a candidate for ACL reconstruction surgery. Patients with multiligamentous injury, those with a history of previous surgery were excluded from the study. All the surgeries were performed by a single surgeon (RG) using the transportal technique. Mean Lysholm score at 2 years' followup was 89.7 ± 9.2 for BPTB graft and 94 ± 8.9 for hamstring tendon graft with sigma 9.05.¹⁹ The sample size came out to be 63 patients in each group at a power of study 80% (confidence interval - 95%). The patients were randomized into two groups according to a random number generated by research fellow (GD) using a computer software (random allocation software). Group I – those who underwent ACL reconstruction was done using free BPTB graft ($n = 80$) and Group II – those who underwent ACL reconstruction was done using semitendinosus-gracilis graft with preserved tibial insertion STGPI graft ($n = 80$). Another examiner (AS) did the allocation using a sealed enveloped system. In BPTB, cohort graft fixation was done at both tibial and femoral side using soft silk screw (Smith and Nephew, USA) and in hamstring cohort graft fixation was done only on the femoral side using EndoButton (Smith and nephew, USA) keeping tibial insertion preserved (free end sutured to its insertion using Ethibond suture).²⁰⁻²² Athletes of both the groups underwent the same rehabilitation protocol postoperatively for 6 months. From day 1, depending on pain tolerance full weight-bearing walking with brace, static quadriceps exercise, straight leg raise, and full range of movement were started. This regime was continued for 6 weeks. After 6 weeks, cycling and half squats were added to this regime. At 3 months, jogging and full squats were allowed. At 6 months, athletes were allowed to play practice game depending on their limb symmetrical index (limb symmetry index >85%; thigh muscle girth and triple hop test).

Anterior translation of tibia for both normal knee and the injured knee was measured using KT-1000 preoperatively, at 6, 12, and 24 months' postoperatively. KT-1000 measurement was done by another examiner (AK) who was blinded to clinical findings, MRI, and arthroscopic

findings. Similarly, the functional status of all the patients was assessed (AK) using the WOMAC score and Lysholm score.

Statistical analysis

Chi-square test was used for comparison of two categorical and independent variables. Unpaired Student's *t*-test was used for quantitative variables (Lysholm score, WOMAC score, and KT-1000 difference).

Results

The present study was conducted on 160 athletes involved in different sports; these sportspersons underwent primary ACL reconstruction using STGPI graft or BPTB graft. Demographic details are described in Tables 1 and 2.

Table 1: Number of patients from different sports who underwent anterior cruciate ligament reconstruction with semitendinosus gracilis graft with preserved tibial insertion and bone-patellar tendon-bone graft

	STGPI	BPTB
Kabaddi	29	38
Football	18	16
Athlete	13	10
Cricket	5	4
Volleyball	1	4
Wrestling	4	1
Badminton	1	1
Basketball	3	2
Judo	1	2
Tycando	1	0
Hockey	2	1
Boxer	0	1
Shotput	1	0
Skating	1	0
Total	80	80

STGPI=Semitendinosus gracilis graft with preserved tibial insertion, BPTB=Bone-patellar tendon-bone

Table 2: Demographic comparison of semitendinosus gracilis graft with preserved tibial insertion and bone-patellar tendon-bone cohort

	STGPI	BPTB	P
Age (years)	24.82±5.04	25±5.81	0.83
Gender (male:female)	78:2	79:1	1
Dominant versus nondominant	53:27	42:38	0.1
BMI (kg/m ²)	22.1±4.87	21.8±4.93	0.7
Concomitant meniscus damage	55	56	0.9
Meniscal repair	5	7	0.7
Concomitant chondral damage	39	40	0.9
Grade 4	4	6	0.7
Grade 3	13	15	0.8
Grade 2	22	19	0.7

STGPI=Semitendinosus gracilis graft with preserved tibial insertion, BPTB=Bone-patellar tendon-bone, BMI=Body mass index

Knee laxity

There was no significant difference in knee laxity between the two grafts at 6 months ($P = 0.07$), 1 year ($P = 0.4$), and 2 years ($P = 0.3$) [Table 3].

Functional assessment

It was observed that there was no significant difference in the Lysholm [Table 4] at 6 months ($P = 0.07$), 1 year ($P = 0.1$), and 2 years ($P = 0.2$) between the two grafts. Similarly, there was no significant difference in WOMAC score [Table 5] at 6 months ($P = 0.17$), 1 year ($P = 0.13$), and 2 years ($P = 0.25$) between two grafts. 53/77 athletes returned to the same level of sports after ACL reconstruction with BPTB graft with mean time to return to sports was 9.78 ± 2.0 months. 40/77 athletes returned to the same level of sports after ACL reconstruction with STGPI graft with mean time to return to sports 10.8 ± 2.1 months. Return to sports was observed to be higher ($P = 0.047$) and early ($P = 0.002$) with BPTB graft.

On followup, the pain was compared between the two groups at 3, 6, 12 months, and 2 years. At 3 months, visual analog scale (VAS) score was 0.84 ± 1.13 in BPTB cohort and 0.72 ± 1.03 in STGPI cohort ($P = 0.48$); at 6 months, VAS score was 0.49 ± 0.87 in BPTB cohort and 0.37 ± 0.76 in STGPI cohort ($P = 0.35$).

Table 3: Comparison of knee laxity between semitendinosus gracilis graft with preserved tibial insertion graft and bone-patellar tendon-bone graft

Mean KT-1000	STGPI graft	BPTB graft	P
At 6 months	2.68±1.54 mm (n=80)	2.27±1.28 mm (n=80)	0.07
At 12 months	2.52±1.60 mm (n=78)	2.31±1.68 mm (n=79)	0.4
At 2 year	2.23±1.23 mm (n=77)	1.98±1.62 mm (n=77)	0.3

STGPI=Semitendinosus gracilis graft with preserved tibial insertion, BPTB=Bone-patellar tendon-bone

Table 4: Comparison of Lyshom score between two grafts at 6 months, 1 year and 2 years

Lyshom score	At 6 months	At 1 year	At 2 years
STGPI	90±5.69	95.5±5.233	96.1±5.81
BPTB	91.5±4.56	96.7±3.91	97.3±4.62
P	0.07	0.1	0.15

STGPI=Semitendinosus gracilis graft with preserved tibial insertion, BPTB=Bone-patellar tendon-bone

Table 5: Comparison of WOMAC score between two grafts at 6 months, 1 year and 2 years

WOMAC score	At 6 months	At 12 months	At 2 years
STGPI	6.5±7.2	3.5±2.29	3.3±2.76
BPTB	5.1±5.6	2.98±2.02	2.84±2.21
P	0.17	0.13	0.25

STGPI=Semitendinosus gracilis graft with preserved tibial insertion, BPTB=Bone-patellar tendon-bone

At 12 months, VAS score was 0.33 ± 0.81 in BPTB cohort and 0.24 ± 0.62 in STGPI cohort ($P = 0.43$). At 2 years, VAS score was 0.16 ± 0.43 in BPTB cohort and 0.14 ± 0.41 in STGPI cohort.

Donor site morbidities

There was scar hypertrophy in 15 patients over BPTB graft harvest site as compared to only 6 patients with that of STGPI group ($P = 0.04$). Hypertrophic scar had only cosmetic importance [Figure 1]. 12/80 patients experienced kneeling pain in the BPTB cohort, whereas we did not find any case of kneeling pain in STGPI cohort. In this study, we found 1 case of heterotrophic calcification with patellar tendon ossification after ACL reconstruction with BPTB graft [Figure 2].

Duration of surgery

ACL reconstruction with STG graft with preserved tibial insertion (34 min) was less time consuming than ACL reconstruction with BPTB graft (48 min).

Graft rupture

Graft rupture rate was 3.75% at followup of 2 years. 6 out of 160 patients (2-year followup) underwent revision ACL surgery, 3 patients from STGPI group [Figure 3] and 3 patients from BPTB group.

Discussion

In this study, it was observed that there was no statistically significant difference in the knee laxity (KT-1000 difference) between two grafts ($P > 0.05$). The evidence available in the literature is inconclusive about the effect of graft on knee laxity; there are some studies which showed that the hamstring tendon graft is associated with more knee laxity as compared to the BPTB graft.^{9,23-26} However, there are some studies which did not find any difference in knee laxity between two grafts.^{17,27-30} Poehling-Monaghan *et al.*²⁸ in their meta-analytic study observed that there was no difference in knee laxity between two groups; these results were contrary to other meta-analytic studies conducted by the Xie *et al.*⁶ and Li *et al.*²⁵ who observed that hamstring tendon graft was inferior to BPTB graft in terms of restoring knee stability.

In this study, there was no difference in functional outcome and postoperative pain between the two groups. Results of this study were similar to the previous studies, where no difference was found between two grafts in terms of functional outcome.^{13-16,31} Stańczak *et al.* in their prospective study observed that type of graft had no effect on the functional outcome of ACL reconstruction.¹¹ Return to sports was observed to be early and higher with BPTB graft as compared to STGPI graft. In previous studies also, it was observed that returned to sports was higher with BPTB graft.³²⁻³⁴



Figure 1: Patients with hypertrophic postoperative scar



Figure 2: Postoperative X-ray showing heterotrophic ossification and patellar tendon calcification

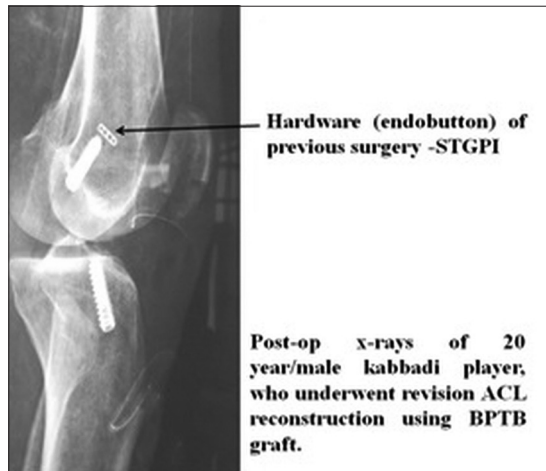


Figure 3: Postoperative X-ray of revision anterior cruciate ligament after semitendinosus gracilis graft with preserved tibial insertion graft rupture

The overall incidence of graft rupture in the present study was 3.75% (6/160) at 2-year followup. Three patients from STGPI group and 3 patients from BPTB group had graft failure. The incidence of graft ruptures ranges from 2.6% to 10% depending on the duration of the study.^{10,32,35} Most of the studies quoted hamstring tendon graft had a higher graft failure rate as compared to BPTB graft.^{9,10} However, some studies did not find any significant difference in the graft failure rate between the two grafts.^{30,36} Tone Gifstad *et al.*¹⁰ and Andreas Persson *et al.*³⁷ in their meta-analytic study observed that BPTB graft is associated with a lower incidence of graft failure as compared to hamstring tendon graft. Leo A. Pinczewski *et al.* in their 10-year prospective study observed no difference in the incidence of graft rupture rate between hamstring tendon graft and BPTB graft.³⁶ A

recent study observed that STGPI graft and BPTB graft are comparable in terms of graft rupture rate.³⁸ This study does have limitation in terms of limited period followup of 2 years; therefore, long term followup is required to see the effect of type of graft on graft rupture rate.

Donor site morbidities such as kneeling pain (15%; 12 out of 80 patients), heterotrophic calcification (1%), and hypertrophic scar (18%; 15 out of 80 patients) were observed to be more with BPTB graft. In previous studies also, donor site morbidities were more commonly reported with BPTB graft as compared to the hamstring graft.^{25,30} The reported incidence of anterior knee pain in previous studies varies from 31% to 54%.^{39,40} We did a proper closure of peritendonium in every patient which might be the cause for a low rate of anterior knee pain in this study. Kohn and Sander-Beurman⁴¹ in their study showed that proper closure of peritendonium reduces the chances of anterior knee pain. In a recent meta-analysis study conducted by A. Hardy *et al.*, the incidence of anterior knee pain was 46%.

Hypertrophic scar was found to be more common with BPTB graft (18%) as compared to STGPI graft (7%). In this study, we found one case of heterotrophic calcification with patellar tendon ossification after ACL reconstruction with BPTB. X-ray of a patient showing heterotrophic calcification and patellar tendon ossification is shown in Figure 2. The incidence of heterotrophic calcification reported in the literature was 1.54%–2.58% and inadvertently scattered bone debris in the operative field was described as the most important cause for it.⁴² Patellar tendon ossification after ACL reconstruction is an extremely rare complication, and till now only three cases have been reported in literature.⁴³⁻⁴⁵

This study had its limitation as more long term followup was required to see the effect of graft type on graft rupture rate. Another drawback was a low number of female patients in our study; the cause of this gender discrepancy is male dominance in sports such as kabaddi and football in our country.

Graft for ACL reconstruction is still a controversial topic. In this study, we observed there was no difference between two grafts in term of knee stability, VAS score, and functional outcome. However, ACL graft surgery with hamstring tendon graft is less time consuming and associated with less donor site morbidity.

Conclusion

There was no difference between two grafts in term of knee stability, visual analog scale score and functional outcome. However, hamstring tendon graft is associated with less donor site morbidity.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patients have given their consent for their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Conflicts of interest

There are no conflicts of interest.

References

- Månsson O, Kartus J, Sernert N. Health-related quality of life after anterior cruciate ligament reconstruction. *Knee Surg Sports Traumatol Arthrosc* 2011;19:479-87.
- Fridén T, Ryd L, Lindstrand A. Laxity and graft fixation after reconstruction of the anterior cruciate ligament. A roentgen stereophotogrammetric analysis of 11 patients. *Acta Orthop Scand* 1992;63:80-4.
- Eriksson K, Anderberg P, Hamberg P, Löfgren AC, Bredenberg M, Westman I, *et al.* A comparison of quadruple semitendinosus and patellar tendon grafts in reconstruction of the anterior cruciate ligament. *J Bone Joint Surg Br* 2001;83:348-54.
- Bourke HE, Salmon LJ, Waller A, Patterson V, Pinczewski LA. Survival of the anterior cruciate ligament graft and the contralateral ACL at a minimum of 15 years. *Am J Sports Med* 2012;40:1985-92.
- Fu FH, Bennett CH, Ma CB, Menetrey J, Lattermann C. Current trends in anterior cruciate ligament reconstruction. Part II. Operative procedures and clinical correlations. *Am J Sports Med* 2000;28:124-30.
- Xie X, Liu X, Chen Z, Yu Y, Peng S, Li Q. A meta-analysis of bone-patellar tendon-bone autograft versus four-strand hamstring tendon autograft for anterior cruciate ligament reconstruction. *Knee* 2015;22:100-10.
- Kartus J, Movin T, Karlsson J. Donor-site morbidity and anterior knee problems after anterior cruciate ligament reconstruction using autografts. *Arthroscopy* 2001;17:971-80.
- Oiestad BE, Holm I, Engebretsen L, Risberg MA. The association between radiographic knee osteoarthritis and knee symptoms, function and quality of life 10-15 years after anterior cruciate ligament reconstruction. *Br J Sports Med* 2011;45:583-8.
- Freedman KB, D'Amato MJ, Nedeff DD, Kaz A, Bach BR Jr. Arthroscopic anterior cruciate ligament reconstruction: A metaanalysis comparing patellar tendon and hamstring tendon autografts. *Am J Sports Med* 2003;31:2-11.
- Gifstad T, Foss OA, Engebretsen L, Lind M, Forssblad M, Albrektsen G, *et al.* Lower risk of revision with patellar tendon autografts compared with hamstring autografts: A registry study based on 45,998 primary ACL reconstructions in Scandinavia. *Am J Sports Med* 2014;42:2319-28.
- Stańczak K, Zielińska M, Synder M, Domzalski M, Polguy M, Sibiński M. Comparison of hamstring and patellar tendon grafts in anterior cruciate ligament reconstruction: A prospective randomized study. *J Int Med Res* 2018;46:785-91.
- Harilainen A, Linko E, Sandelin J. Randomized prospective study of ACL reconstruction with interference screw fixation in patellar tendon autografts versus femoral metal plate suspension and tibial post fixation in hamstring tendon autografts: 5-year clinical and radiological follow-up results. *Knee Surg Sports Traumatol Arthrosc* 2006;14:517-28.
- Shaktawat DS, Mishra AK, Kashid MR, Chaudhry A, Stanely A. Comparative study between bone patellar tendon bone and quadrupled hamstring autografts in arthroscopic anterior cruciate ligament reconstruction with aperture fixation. *Int J Res Orthop* 2017;3:185-9.
- Kautzner J, Kos P, Hanus M, Trc T, Havlas V. A comparison of ACL reconstruction using patellar tendon versus hamstring autograft in female patients: A prospective randomised study. *Int Orthop* 2015;39:125-30.
- Gifstad T, Drogset JO, Viset A, Grøntvedt T, Hortemo GS. Inferior results after revision ACL reconstructions: A comparison with primary ACL reconstructions. *Knee Surg Sports Traumatol Arthrosc* 2013;21:2011-8.
- Gobbi A, Francisco R. Factors affecting return to sports after anterior cruciate ligament reconstruction with patellar tendon and hamstring graft: A prospective clinical investigation. *Knee Surg Sports Traumatol Arthrosc* 2006;14:1021-8.
- Goldblatt JP, Fitzsimmons SE, Balk E, Richmond JC. Reconstruction of the anterior cruciate ligament: Meta-analysis of patellar tendon versus hamstring tendon autograft. *Arthroscopy* 2005;21:791-803.
- Gupta R, Bahadur R, Malhotra A, Masih GD, Sood M, Gupta P, *et al.* Outcome of hamstring autograft with preserved insertions compared with free hamstring autograft in anterior cruciate ligament surgery at 2-year follow-up. *Arthroscopy* 2017;33:2208-16.
- Wagner M, Käab MJ, Schallock J, Haas NP, Weiler A. Hamstring tendon versus patellar tendon anterior cruciate ligament reconstruction using biodegradable interference fit fixation: A prospective matched-group analysis. *Am J Sports Med* 2005;33:1327-36.
- Gupta R, Bahadur R, Malhotra A, Masih GD, Gupta P. Anterior cruciate ligament reconstruction using hamstring tendon autograft with preserved insertions. *Arthrosc Tech* 2016;5:e269-74.
- Zhang Q, Yang Y, Li J, Zhang H, Fu Y, Wang Y. Functional double-bundle anterior cruciate ligament reconstruction using hamstring tendon autografts with preserved insertions is an effective treatment for tibiofemoral instability. *Knee Surg Sports Traumatol Arthrosc* 2019;27:1-10.
- Kim SJ, Kim HK, Lee YT. Arthroscopic anterior cruciate ligament reconstruction using autogenous hamstring tendon graft without detachment of the tibial insertion. *Arthroscopy* 1997;13:656-60.
- Feller JA, Webster KE. A randomized comparison of patellar tendon and hamstring tendon anterior cruciate ligament reconstruction. *Am J Sports Med* 2003;31:564-73.
- Bizzini M, Gorelick M, Munzinger U, Drobny T. Joint laxity and isokinetic thigh muscle strength characteristics after anterior cruciate ligament reconstruction: Bone patellar tendon bone versus quadrupled hamstring autografts. *Clin J Sport Med* 2006;16:4-9.
- Li S, Chen Y, Lin Z, Cui W, Zhao J, Su W. A systematic review

- of randomized controlled clinical trials comparing hamstring autografts versus bone-patellar tendon-bone autografts for the reconstruction of the anterior cruciate ligament. *Arch Orthop Trauma Surg* 2012;132:1287-97.
26. Cristiani R, Sarakatsianos V, Engström B, Samuelsson K, Forsblad M, Ståhlman A. Increased knee laxity with hamstring tendon autograft compared to patellar tendon autograft: A cohort study of 5462 patients with primary anterior cruciate ligament reconstruction. *Knee Surg Sports Traumatol Arthrosc* 2019;27:381-8.
 27. Drogset JO, Strand T, Uppheim G, Odegård B, Bøe A, Grøntvedt T. Autologous patellar tendon and quadrupled hamstring grafts in anterior cruciate ligament reconstruction: A prospective randomized multicenter review of different fixation methods. *Knee Surg Sports Traumatol Arthrosc* 2010;18:1085-93.
 28. Poehling-Monaghan KL, Salem H, Ross KE, Seerist E, Ciccotti MC, Tjoumakaris F, *et al.* Long-term outcomes in anterior cruciate ligament reconstruction: A systematic review of patellar tendon versus hamstring autografts. *Orthop J Sports Med* 2017;5:2325967117709735.
 29. Ahldén M, Kartus J, Ejerhed L, Karlsson J, Sernert N. Knee laxity measurements after anterior cruciate ligament reconstruction, using either bone-patellar-tendon-bone or hamstring tendon autografts, with special emphasis on comparison over time. *Knee Surg Sports Traumatol Arthrosc* 2009;17:1117-24.
 30. Riaz O, Aqil A, Mannan A, Hossain F, Ali M, Chakrabarty G, *et al.* Quadriceps tendon-bone or patellar tendon-bone autografts when reconstructing the anterior cruciate ligament: A meta-analysis. *Clin J Sport Med* 2018;28:316-24.
 31. Leys T, Salmon L, Waller A, Linklater J, Pinczewski L. Clinical results and risk factors for reinjury 15 years after anterior cruciate ligament reconstruction: A prospective study of hamstring and patellar tendon grafts. *Am J Sports Med* 2012;40:595-605.
 32. Heijne A, Werner S. A 2-year follow-up of rehabilitation after ACL reconstruction using patellar tendon or hamstring tendon grafts: A prospective randomised outcome study. *Knee Surg Sports Traumatol Arthrosc* 2010;18:805-13.
 33. Mascarenhas R, Tranovich MJ, Kropf EJ, Fu FH, Harner CD. Bone-patellar tendon-bone autograft versus hamstring autograft anterior cruciate ligament reconstruction in the young athlete: A retrospective matched analysis with 2-10 year follow-up. *Knee Surg Sports Traumatol Arthrosc* 2012;20:1520-7.
 34. Nwachukwu BU, Voleti PB, Berkanish P, Chang B, Cohn MR, Williams RJ 3rd, *et al.* Return to play and patient satisfaction after ACL reconstruction: Study with minimum 2-year follow-up. *J Bone Joint Surg Am* 2017;99:720-5.
 35. Wright RW, Gill CS, Chen L, Brophy RH, Matava MJ, Smith MV, *et al.* Outcome of revision anterior cruciate ligament reconstruction: A systematic review. *J Bone Joint Surg Am* 2012;94:531-6.
 36. Pinczewski LA, Lyman J, Salmon LJ, Russell VJ, Roe J, Linklater J. A 10-year comparison of anterior cruciate ligament reconstructions with hamstring tendon and patellar tendon autograft: A controlled, prospective trial. *Am J Sports Med* 2007;35:564-74.
 37. Persson A, Fjeldsgaard K, Gjertsen JE, Kjellsen AB, Engebretsen L, Hole RM, *et al.* Increased risk of revision with hamstring tendon grafts compared with patellar tendon grafts after anterior cruciate ligament reconstruction: A study of 12,643 patients from the norwegian cruciate ligament registry, 2004-2012. *Am J Sports Med* 2014;42:285-91.
 38. Gupta R, Sood M, Malhotra A, Masih GD, Kapoor A, Raghav M, *et al.* Low re-rupture rate with BPTB autograft and semitendinosus gracilis autograft with preserved insertions in ACL reconstruction surgery in sports persons. *Knee Surg Sports Traumatol Arthrosc* 2018;26:2381-8.
 39. Roe J, Pinczewski LA, Russell VJ, Salmon LJ, Kawamata T, Chew M. A 7-year follow-up of patellar tendon and hamstring tendon grafts for arthroscopic anterior cruciate ligament reconstruction: Differences and similarities. *Am J Sports Med* 2005;33:1337-45.
 40. Corry IS, Webb JM, Clingeleffer AJ, Pinczewski LA. Arthroscopic reconstruction of the anterior cruciate ligament. A comparison of patellar tendon autograft and four-strand hamstring tendon autograft. *Am J Sports Med* 1999;27:444-54.
 41. Kohn D, Sander-Beuermann A. Donor-site morbidity after harvest of a bone-tendon-bone patellar tendon autograft. *Knee Surg Sports Traumatol Arthrosc* 1994;2:219-23.
 42. Bhandary B, Shetty S, Bangera VV, Yogaparakash R, Kassim MS, Alva K, *et al.* To study the incidence of heterotopic ossification after anterior cruciate ligament reconstruction. *J Clin Diagn Res* 2013;7:888-91.
 43. Erdil M, Aşık M, Sen C, Polat G. Heterotopic bone formation following anterior cruciate ligament reconstruction with BPTB autograft. *Acta Orthop Traumatol Turc* 2012;46:72-6.
 44. Valencia H, Gavín C. Infrapatellar heterotopic ossification after anterior cruciate ligament reconstruction. *Knee Surg Sports Traumatol Arthrosc* 2007;15:39-42.
 45. Camillieri G, Di Sanzo V, Ferretti M, Calderaro C, Calvisi V. Patellar tendon ossification after anterior cruciate ligament reconstruction using bone – Patellar tendon – Bone autograft. *BMC Musculoskelet Disord* 2013;14:164.