



Summary

Introduction: Aim of this study was to see the effect of quadruple hamstring tendon graft diameter on knee stability, functional outcome, and graft rupture risk after ACL reconstruction.

Method: This study had two parts retrospective part and prospective part. In retrospective part, 18 athletes who underwent revision ACL reconstruction surgery between years 2008 and 2015 were identified from the computerized database. In prospective part, 103 athletes who underwent primary ACL reconstruction were enrolled in the study and divided into two groups depending upon their quadruple hamstring tendon graft diameter – group A (graft diameter <8 mm) and group B (≥ 8 mm).

Results: In retrospective study, 16/18 athletes who underwent revision ACL surgery had graft size <8 mm and 2 had graft size ≥ 8 mm. In prospective study, 69 patients had graft size <8 mm and 34 patients had graft size ≥ 8 mm. Mean graft size was 7.56 ± 0.53 mm. 2/69 patients in group A had graft rupture and none of the patients in group B had suffered from graft rupture. KT-1000 difference measured at 1 year was 2.57 ± 1.67 mm and 1.87 ± 1.02 mm with groups A and B respectively (p -value = 0.03). Return to sports was significantly higher with graft size ≥ 8 mm (20/34) as compared to graft size <8 mm (21/69; p -value = 0.01). Lysholm score and WOMAC score were comparable in both the groups at 6 months and 12 months (p -value >0.05).

Conclusion: Graft size of <8 mm is a risk factor for ACL graft rupture. Graft size of ≥ 8 mm provides better knee stability and higher return to sports.

Keywords

Graft size – Graft rupture – ACL – Hamstring tendon graft

ORIGINAL PAPER

Does hamstring tendon graft diameter affect the outcome of anterior cruciate ligament surgery?

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Introduction

Most of the sportsperson with ACL tear eventually undergo ACL reconstruction with either hamstring tendon graft or bone-patellar tendon-bone graft (BPTB). Till late 1990s BPTB graft was considered as a gold standard graft for ACL reconstruction. However, due to donor site morbidities with BPTB graft [9,12] trend is shifting towards the hamstring tendon graft. Hamstring tendon graft has similar functional and clinical outcome but with less donor site morbidity [8,11]. However, it is observed to be associated with more knee laxity [6], higher incidence of graft rupture [22] and lower return to sports as compared to BPTB graft [4,7]. Unlike BPTB graft where graft size is fixed, hamstring tendon graft has variable diameter which varies from person to person depending on their height [14,20,23,28]. It was previously reported that smaller size graft is more prone to graft re-rupture [3,15,17,20,25]. Conte et al. in their systematic review study reported that patients having graft

size less than 8 mm have 6.8 times greater relative risk of graft rupture as compared to graft size more than 8 mm [3]. Effect of graft diameter on functional outcome of ACL reconstruction is not extensively studied. Purpose of the study was to identify the effect of graft diameter on knee stability, functional outcome, and risk of graft rupture.

Material and methods

This study has two parts; retrospective and prospective part. We analyzed the data from years 2010 to 2015 and identified 18 patients with graft rupture who had met the inclusion criteria. Inclusion criteria were male patients, aged between 18 and 40 years, in whom primary ACL reconstruction was done using hamstring tendon graft, details of graft size were available, and false tunnel placement was not a cause of graft failure. In prospective study (January 2014 to January 2018), we conducted a study on 103 sports-persons who underwent primary ACL

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Beeinflusst der Hamstringsehnen Durchmesser die Ergebnisse nach vorderer Kreuzbandersatzplastik?

Zusammenfassung

Einleitung: Das Ziel dieser Studie war es, den Effekt des Sehnen Durchmessers einer Vierfach-Hamstringsehne auf Kniestabilität, funktionelles Outcome und Transplantatruptur nach VKB-Rekonstruktion zu untersuchen.

Methoden: Diese Studie besteht aus einem retrospektiven und einem prospektiven Teil. Retrospektiv wurden 18 Athleten mit VKB-Revision in den Jahren 2008 bis 2015 eingeschlossen, die über eine Computerdatenbank identifiziert wurden. Im prospektiven Teil wurden 103 Athleten mit primärer VKB-Rekonstruktion eingeschlossen und anschließend in zwei Gruppen in Abhängigkeit vom Durchmesser der Vierfach-Hamstringssehnen eingeteilt (Gruppe A: $<8\text{mm}$ und Gruppe B: $\leq 8\text{mm}$).

Ergebnisse: In der retrospektiven Studie zeigten 16/18 Athleten, die sich einer VKB-Revision unterzogen, einen Transplantatdurchmesser $<8\text{ mm}$ und 2 einen Transplantatdurchmesser $\geq 8\text{ mm}$. In der prospektiven Studie wiesen 69 Patienten einen Transplantatdurchmesser $<8\text{ mm}$ und 34 einen Transplantatdurchmesser $\geq 8\text{ mm}$ auf. Der mittlere Transplantatdurchmesser betrug $7,56 \pm 0,53\text{ mm}$. 2/69 Patienten in Gruppe A zeigten eine Transplantatruptur und kein Patient in Gruppe B. KT-1000 Differenz gemessen nach 1 Jahr betrug $2,57 \pm 1,67\text{ mm}$ und $1,87 \pm 1,02\text{ mm}$ in Gruppe A und B respektiv ($p\text{-Wert}=0,03$). Return to Sports war signifikant höher bei Transplantatdurchmessern $\geq 8\text{ mm}$ (20/34) verglichen mit Transplantatdurchmessern $<8\text{ mm}$ (21/69; $p\text{-Wert} = 0,01$). Lysholm Score und WOMAC Score waren vergleichbar in beiden Gruppen nach 6 und 12 Monaten ($p\text{-Wert} > 0,05$).

Zusammenfassung: Ein Transplantatdurchmesser $<8\text{ mm}$ ist ein Risikofaktor für VKB-Transplantatruptur. Ein

reconstruction using quadruple hamstring tendon graft with preserved tibial insertion and fixed with endobutton [10]. Graft size was measured using graft sizer and documented at the time of surgery. Patients were divided into two groups; group A ($<8\text{ mm}$) and group B ($\geq 8\text{ mm}$) and same rehabilitation protocol was followed for both the groups. Patients were regularly followed up at 3 months, 6 months and 1 year. KT-1000, Lysholm score and WOMAC score were calculated at 6 months and 1 year. Inclusion criteria were male sportsperson, aged less than 40 years and skeletal maturity. Exclusion criteria were ACL tear associated another ligament injury (PCL, MCL PLC), and previously operated on the same knee, female patient. All patients were followed up for minimum of 12 months. The institutional ethics committee had approved this study and all the participants had given informed consent for this study.

Results

In retrospective part of the study, 18 patients underwent revision ACL reconstruction. Mean age was 24.28 ± 3.00 years. Mean time for graft rupture was 4.2 years. Out of the total 18 patients, 16 patients (89%) had graft size less than 8 mm and 2 patients (11%) had graft size more than 8 mm.

In a prospective part of the study, 103 sportspersons underwent primary ACL reconstruction using quadruple hamstring tendon graft with preserved tibial insertion. Mean age was 25.14 ± 5.74 years. 55 patients had an injury on a non-dominant limb and 48 patients had an injury on a dominant limb. 34 patients had quadruple hamstring tendon graft diameter of $\geq 8\text{ mm}$ and 69 patients had less than

8 mm. Mean graft size was $7.56 \pm 0.53\text{ mm}$. Mean follow-up time was 22 months (range 34–12 months).

The difference in anterior translation of tibia between normal and operated knee was measured using KT-1000 showed no statistically significant difference between two groups at 6 months (Table 1) ($p\text{-value} = 0.1$). However, at 1-year knee stability was observed to be significantly more with hamstring tendon graft size $\geq 8\text{ mm}$ as compared to $<8\text{ mm}$ ($p\text{-value} = 0.03$). 2/103 patients had graft rupture and both the patients had graft diameter $<8\text{ mm}$. Significantly higher number of patients returned to sports in group B (20/34) as compared to group A (21/69; $p\text{-value} = 0.005$). Functional outcome was measured using Lysholm score and WOMAC score (Table 1). There was no significant difference in functional outcome between two groups ($p\text{-value} > 0.05$).

Statistical method

Summary statistics including means and standard deviations were calculated for normally distributed continuous variables. Correlation between graft size and return to sports was calculated by chi-square test. The relationship between graft size, knee stability and functional outcome was evaluated using unpaired student *t*-test.

Discussion

In the retrospective part of the study, 89% (16/18) of the patients who underwent revision ACL surgery had graft diameter less than 8 mm and in prospective study also, 2 patients who underwent revision ACL reconstruction surgery had graft diameter less than 8 mm. In

Durchmesser von ≥ 8 mm zeigt bessere Kniestabilität und höheren Return to Sports.

Schlüsselwörter

Transplantatdurchmesser – Transplantatruptur – VKB – Hamstring Sehnen Transplantat

Table 1. Summary of stability, functional score, return to sports and graft rupture after ACL reconstruction.

	Group B (graft size ≥ 8 mm; $n = 34$)	Group A (graft size < 8 mm; $n = 69$)	<i>p</i> -value
KT-1000 difference at 6 months	2.14 \pm 1.09 mm	2.61 \pm 1.45 mm	0.1 ^{α}
KT-1000 difference at 12 months	1.87 \pm 1.02 mm	2.57 \pm 1.67 mm	0.03^{α}
Number of patients return to sports same level at 1 year	20 (59%)	21 (30%)	0.005^{β}
Mean time to return to sports	10.29 \pm 1.57 months	10.1 \pm 1.31 months	0.51 ^{α}
Lysholm score at 6 months	90.5 \pm 5.04	90.1 \pm 6.1	0.74 ^{α}
Lysholm score at 12 months	95.8 \pm 4.39	94.8 \pm 5.84	0.37 ^{α}
WOMAC score at 6 months	2.66 \pm 1.65	2.82 \pm 2.3	0.72 ^{α}
WOMAC score at 12 months	0.91 \pm 1.31	1.4 \pm 2.04	0.19 ^{α}
Graft rupture	0	2 (3%)	

α – unpaired *t*-test; β – chi-square test.

A bold letter indicate that value is statistically significant.

previously published literature reported incidence of graft failure after ACL reconstruction was 4.2%–5.8% [29]. Most described causes of graft failure are femoral tunnel malposition [26] and re-trauma [18]. Quadruple hamstring tendon graft diameter of less than 8 mm is another described risk factor for ACL graft rupture [2,3,15,17,20].

Hamstring tendon diameter depends upon height and BMI of the patients [14,16,20,23,28]; therefore it can vary according to the geographic variation [24]. In present study, mean graft size was 7.56 \pm 0.53 mm which is smaller as compared to previously published results where mean graft size was 7.9–8.1 mm [2,14,15,25]. This could be because of difference in mean height of the studied population as most of the previous studies were conducted on non-Asian population. A study

conducted by Park et al. on Asian population graft size was observed to be 7.2 \pm 0.7 mm [20]. As hamstring tendon graft size of < 8 mm is a risk factor for ACL rupture, it raises the concern as graft diameter ≥ 8 mm is not very common in Asian population. To counter this problem patellar tendon graft or various methods to augment or enhance graft size can be used in patients who have graft diameter less than 8 mm [5,13,19,21]. For better planning of surgery graft size can be calculated pre-operatively by using the patient's height and BMI [1,27,28,30].

In the present study, it was observed that patients with graft diameter ≥ 8 mm had more knee stability at 12 months as compared to patients with graft diameter < 8 mm (*p*-value = 0.03). Even after extensive search, we could not find any study in the literature which studied the

effect of graft diameter on knee stability. Returned to sports was significantly higher in patients with graft diameter ≥ 8 mm (20/34) as compared to patients with graft diameter < 8 mm (21/69). However, functional outcome (Lysholm and WOMAC score) was comparable between two groups (p -value > 0.05). Results are contrary to previously published literature which observed that small graft size associated with poor functional outcome. Mariscalco et al. reported that smaller graft is poor predictor of KOOS score [17]. Mean reported time to revision surgery was 12.7 months [17] which is very early as compared to our study where it was 48 months. Short time frame of prospective study (12 months follow-up) was the weakness of this study. Study with long follow-up required to see the effect of graft size on graft rupture.

Conclusion

Graft diameter < 8 mm is a risk factor for ACL graft rupture. Graft size of ≥ 8 mm has better knee stability and higher incidence of returning to sports. However, graft size has no impact on the functional outcome of ACL reconstruction surgery.

Practical implication

The incidence of graft failure can be reduced by better pre-operative planning. In sportsperson hamstring graft size of > 8 mm is preferable. If pre-operatively expected graft size is < 8 mm then graft augmentation or BPTB graft should be used to decrease the risk of graft failure and increase chances of return of sports.

Conflict of interest

The authors declare that they have no conflict of interest

References

- [1] M. Çeliktaş, A. Gölpınar, Ö. Köse, Z. Sütölk, K. Çelebi, Y. Sarpel, Prediction of the quadruple hamstring autograft thickness in ACL reconstruction using anthropometric measures, *Acta Orthop. Traumatol. Turcica* 47 (1) (2013) 14–18.
- [2] M. Clatworthy, Graft Diameter matters in Hamstring ACL reconstruction, *Orthop. J. Sports Med.* 4 (7) (2016), 2325967116S2325900082.
- [3] E.J. Conte, A.E. Hyatt, C.J. Gatt, A. Dhawan, Hamstring autograft size can be predicted and is a potential risk factor for anterior cruciate ligament reconstruction failure, *Arthrosc. J. Arthrosc. Rel. Surg.* 30 (7) (2014) 882–890.
- [4] I.S. Corry, J.M. Webb, A.J. Clingeffer, L.A. Pinczewski, Arthroscopic reconstruction of the anterior cruciate ligament. A comparison of patellar tendon autograft and four-strand hamstring tendon autograft, *Am. J. Sports Med.* 27 (4) (1999) 444–454.
- [5] J.E. Darnley, B. Léger-St-Jean, A.D. Pedroza, D.C. Flanigan, C.C. Kaeding, R.A. Magnussen, Anterior cruciate ligament reconstruction using a combination of autograft and allograft tendon: a MOON cohort study, *Orthop. J. Sports Med.* 4 (7) (2016), 2325967116662249.
- [6] M.C. Forster, I.W. Forster, Patellar tendon or four-strand hamstring? A systematic review of autografts for anterior cruciate ligament reconstruction, *Knee* 12 (3) (2005) 225–230.
- [7] F.H. Fu, C.H. Bennett, C.B. Ma, J. Menetrey, C. Lattermann, Current trends in anterior cruciate ligament reconstruction. Part II. Operative procedures and clinical correlations, *Am. J. Sports Med.* 28 (1) (2000) 124–130.
- [8] T. Gifstad, J.O. Drogset, A. Viset, T. Grøntvedt, G.S. Hortemo, Inferior results after revision ACL reconstructions: a comparison with primary ACL reconstructions, *Knee Surg. Sports Traumatol. Arthrosc.* 21 (9) (2013) 2011–2018.
- [9] J.P. Goldblatt, S.E. Fitzsimmons, E. Balk, J.C. Richmond, Reconstruction of the anterior cruciate ligament: meta-analysis of patellar tendon versus hamstring tendon autograft, *Arthrosc. J. Arthrosc. Rel. Surg.* 21 (7) (2005) 791–803.
- [10] R.K. Gupta, S. Aggarwal, V. Aggarwal, S.K. Garg, S. Kumar, Preserved insertions of the semitendinosus and gracilis tendons (STG) in ACL reconstruction: a new surgical technique with preliminary results, *Curr. Orthop. Pract.* 21 (4) (2010) 409–414.
- [11] J. Kautzner, P. Kos, M. Hanus, T. Trc, V. Havlas, A comparison of ACL reconstruction using patellar tendon versus hamstring autograft in female patients: a prospective randomised study, *Int. Orthop.* 39 (1) (2015) 125–130.
- [12] G. Laxdal, J. Kartus, L. Hansson, M. Heidvall, L. Ejerhed, J. Karlsson, A prospective randomized comparison of bone-patellar tendon-bone and hamstring grafts for anterior cruciate ligament reconstruction, *Arthrosc. J. Arthrosc. Rel. Surg.* 21 (1) (2005) 34–42.
- [13] R.J. Lee, T.J. Ganley, The 5-strand hamstring graft in anterior cruciate ligament reconstruction, *Arthrosc. Techn.* 3 (5) (2014) e627–e631.
- [14] C.B. Ma, E. Keifa, W. Dunn, F.H. Fu, C.D. Harner, Can pre-operative measures predict quadruple hamstring graft diameter? *Knee* 17 (1) (2010) 81–83.
- [15] R.A. Magnussen, J.T.R. Lawrence, R.L. West, A.P. Toth, D.C. Taylor, W.E. Garrett, Graft size and patient age are predictors of early revision after anterior cruciate ligament reconstruction with hamstring autograft, *Arthrosc. J. Arthrosc. Rel. Surg.* 28 (4) (2012) 526–531.
- [16] M. Mardani-Kivi, M. Karimi-Mobarakeh, A. Mirbolook, S. Keyhani, K. Saheb-Ekhtiari, K. Hashemi-Motlagh, P. Porteghali, Predicting the hamstring tendon diameter using anthropometric parameters, *Arch. Bone Joint Surg.* 4 (4) (2016) 314–317.
- [17] M.W. Mariscalco, D.C. Flanigan, J. Mitchell, A.D. Pedroza, M.H. Jones, J.T. Andrich, R.D. Parker, C.C. Kaeding, R.A. Magnussen, The influence of hamstring autograft size on patient-reported outcomes and risk of revision after anterior cruciate ligament reconstruction: a Multicenter Orthopaedic Outcomes Network (MOON) Cohort Study, *Arthrosc. J. Arthrosc. Rel. Surg.* 29 (12) (2013) 1948–1953.

- [18] B. Marquass, T. Engel, P. Hepp, J.D. Theopold, C. Josten, One- and two-stage procedure for revision after failure of anterior cruciate ligament reconstruction, *Zeitschr. Orthop. Unfallchir.* 145 (6) (2007) 712–718.
- [19] K.W. Nha, G.M. Shetty, J.H. Ahn, Y.S. Lee, D.J. Chae, H.W. Nam, D.H. Lee, Augmentation of autologous hamstring graft during anterior cruciate ligament reconstruction using the bone chip technique, *Knee Surg. Sports Traumatol. Arthrosc.* 18 (1) (2010) 89–91.
- [20] S.Y. Park, H. Oh, S. Park, J.H. Lee, S.H. Lee, K.H. Yoon, Factors predicting hamstring tendon autograft diameters and resulting failure rates after anterior cruciate ligament reconstruction, *Knee Surg. Sports Traumatol. Arthrosc.* 21 (5) (2013) 1111–1118.
- [21] K. Park, C.M. Brusalis, T.J. Ganley, The 8-strand hamstring autograft in anterior cruciate ligament reconstruction, *Arthrosc. Techn.* 5 (5) (2016) e1105–e1109.
- [22] A. Persson, K. Fjeldsgaard, J.-E. Gjertsen, A.B. Kjellsen, L. Engebretsen, R.M. Hole, J.M. Fevang, 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.* 42 (2) (2014) 285–291.
- [23] R. Schwartzberg, B. Burkhart, C. Lariviere, Prediction of hamstring tendon autograft diameter and length for anterior cruciate ligament reconstruction, *Am. J. Orthop. (Belle Mead, NJ)* 37 (3) (2008) 157–159.
- [24] K. Silventoinen, S. Sammalisto, M. Perola, D.I. Boomsma, B.K. Cornes, C. Davis, L. Dunkel, M. De Lange, J.R. Harris, J.V. Hjelmborg, Heritability of adult body height: a comparative study of twin cohorts in eight countries, *Twin Res. Hum. Genet.* 6 (5) (2003) 399–408.
- [25] L. Spragg, J. Chen, R. Mirzayan, R. Love, G. Maletis, The effect of autologous hamstring graft diameter on the likelihood for revision of anterior cruciate ligament reconstruction, *Am. J. Sports Med.* 44 (6) (2016) 1475–1481.
- [26] N.P. Thomas, R. Kankate, F. Wandless, H. Pandit, Revision anterior cruciate ligament reconstruction using a 2-stage technique with bone grafting of the tibial tunnel, *Am. J. Sports Med.* 33 (11) (2005) 1701–1709.
- [27] S. Thomas, R. Bhattacharya, J. Saltikov, D. Kramer, Influence of anthropometric features on graft diameter in ACL reconstruction, *Arch. Orthop. Trauma Surg.* 133 (2) (2013) 215–218.
- [28] J.M. Tuman, D.R. Diduch, L.J. Rubino, J.A. Baumfeld, H.S. Nguyen, J.M. Hart, Predictors for hamstring graft diameter in anterior cruciate ligament reconstruction, *Am. J. Sports Med.* 35 (11) (2007) 1945–1949.
- [29] R.W. Wright, C.S. Gill, L. Chen, R.H. Brophy, M.J. Matava, M.V. Smith, N. A. Mall, Outcome of revision anterior cruciate ligament reconstruction: a systematic review, *J. Bone Joint Surg. Am. Vol.* 94 (6) (2012) 531–536.
- [30] G. Xie, X. Huangfu, J. Zhao, Prediction of the graft size of 4-stranded semitendinosus tendon and 4-stranded gracilis tendon for anterior cruciate ligament reconstruction: a Chinese Han patient study, *Am. J. Sports Med.* 40 (5) (2012) 1161–1166.

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