Observational Study

Medicine®

OPEN

Comparison between single- and double-bundle anterior cruciate ligament reconstructions for knee with grade 2 medial collateral ligament injury

Lian-Xu Chen, PhD[a], Hong-Hong Wang, PhD[b,*]

Abstract

This research discussed clinical outcomes of anterior cruciate ligament reconstruction accompanied by conservative treatment for grade 2 medial collateral ligament injury, and comparison was performed between double-bundle and single-bundle anterior cruciate ligament reconstruction.

Clinical information was retrospectively collected for 41 cases suffering anterior cruciate ligament injuries accompanied by grade 2 medial collateral ligament injuries. Within 14 days after their injuries 22 cases received single-bundle anterior cruciate ligament reconstruction (SB group), while 19 were treated with double-bundle medial collateral ligament reconstruction (DB group). Physical statuses were estimated based on International Knee Documentation Committee (IKDC) and Lysholm scores, Lachman, pivot shift and manual valgus test, and range of motion (ROM), while side-to-side difference was estimated through KT 2000 arthometer.

Anterior cruciate ligament reconstruction accompanied by conservative treatment showed significantly improved anteroposterior, rotational and valgus stability, and IKDC and Lysholm scores (in comparison to pre-operative status, $P < .05$). Incidence of pivot shift was dramatically lower in DB group (2/19) than in SB group (7/22 and 2/22; $P = .028$). No substantial dissimilarity existed between DB and SB groups either in Lachman and valgus tests, KT 2000, ROM, IKDC, or Lysholm scores.

Anterior cruciate ligament reconstruction accompanied by conservative treatment could achieve outstanding stability and functional manifestations for cases facing anterior cruciate ligament injury accompanied by grade 2 medial collateral ligament injury. Moreover, double-bundle anterior cruciate ligament reconstruction is superior to single-bundle operation in treating rotational instability of the knee.

Level of evidence: Retrospective comparative study, Level III.

Abbreviations: ACL = anterior cruciate ligament, AM = anteromedial, DB = double-bundle, IKDC = International Knee Documentation Committee, MCL = medial collateral ligament, PL = posterolateral, SB = single-bundle, STG = semitendinosus and gracilis.

Keywords: anterior cruciate ligament, clinical outcomes, double-bundle reconstruction, medial collateral ligament, single-bundle reconstruction

1. Introduction

Normal anterior cruciate ligament (ACL) and medial collateral ligament (MCL) could avoid anteromedial shifting of the knee and restrict joint valgus opening.[1–3] The combination of ACL and MCL injuries cause anteromedial instability in knee, accounting for 20% of the whole knee ligament injuries.[4] Clinical treatments for such combined injuries are controversial. Some scholars recommend to mend both ligaments simultaneously through surgical operations,[5–7] while others claim that fine results could be achieved via the combination of repairing MCL alone in surgical with non-operative ACL reconstruction.[8,9] Commonly, surgical operation is not indispensable for mending MCL injuries if ACL is reconstructed through tendon graft among those suffering combined ACL and MCL injuries,[9–12] because MCL possesses outstanding capability for healing, according to both animal and clinical researches.[13–15] Reportedly, ACL reconstruction accompanied by conservative treatment may avoid late valgus unsteadiness.[16]

ACL contains 2 bundles with reverse functions: namely anteromedial (AM) and posterolateral (PL) bundles. Single-bundle

Editor: Bo Liu.

The authors have no funding and conflicts of interests to disclose.

All data generated or analyzed during this study are included in this published article [and its supplementary information files].

[a] Department of Orthopaedic, Beijing Tsinghua Changgung Hospital, School of Clinical Medicine, Tsinghua University, [b] Department of Emergency, Beijing University of Chinese Medicine Third Affiliated Hospital, Beijing, China.

[*] Correspondence: Hong-Hong Wang, Department of Emergency, Beijing University of Chinese Medicine Third Affiliated Hospital, Beijing, China (e-mail: bfghhh@126.com).

How to cite this article: Chen LX, Wang HH. Comparison between single- and double-bundle anterior cruciate ligament reconstructions for knee with grade 2 medial collateral ligament injury. Medicine 2021;100:11(e24846).

Received: 19 February 2020 / Received in final form: 3 December 2020 / Accepted: 28 January 2021

http://dx.doi.org/10.1097/MD.0000000000024846

(SB) ACL reconstruction could restore anatomy and kinematics for AM bundle.[17] Frequently, traditional SB reconstruction could reach adequate outcomes, but still face rotational instability and long-term sequelae of degeneration.[18,19] In an earlier biomechanical research, SB ACL reconstruction was incompetent in administering anteroposterior translation and rotation in extension.[20] Consequently, double-bundle (DB) ACL reconstruction might revitalize regular kinematics, and obtain acceptable clinical and biomechanical outcomes.[21–23] In treating combined ACL and MCL injuries, it is difficult to determine whether SB or DB ACL reconstruction should be adopted. Until now, no persuasive proof has been acquired to adjudge whether SB or DB reconstruction is more superior.

The present study was performed to compare clinical outcomes between SB and DB techniques in ACL reconstruction for grade 2 MCL injuries.

2. Materials and methods

Retrospective analyses were performed in Beijing University of Chinese Medicine Third Affiliated Hospital Enrolled cases were treated between 2009 and 2016. Inclusion criteria were as follows:

1. with diagnosed grade 2 injury; and
2. receiving ACL reconstruction within 14 days after injury.

Moreover, patients would be excluded from the study if they had a history of ligamentous injuries in contralateral knee or injuries in ipsilateral knee. Additionally, all the patients were followed up for a minimum of 1 year. The patients who had total meniscectomy, PCL injury, lateral collateral ligament injury, posterolateral rotatory instability, fracture around knee, and grade 1 or 3 MCL injury were excluded from this study. The diagnosis of grade 2 injury was based on the following criteria: the disruption of more fibers, common fibers of superficial MCL with the preservation of partial deep MCL, more generalized tenderness with 5 to 10 mm of joint line opening in examination, and a moderately firm endpoint. A total of 142 patients were diagnosed with ACL rupture combined with grade 2 MCL injury in knee, and 83 patients received primary arthroscopic ACL reconstruction with semitendinosus and gracilis (STG) tendon autografts within 14 days after injury. According to the inclusion and exclusion criteria, 41 eligible cases were finally included in this study. Twenty two patients receiving SB ACL reconstruction were included in the SB group, and 19 patients treated with DB ACL reconstruction were divided into DB group. In SB group, the patients (13 males and 9 females) were aged between 15 and 43 years, with a median age of 24 years. Right knee was affected in 10 patients and injury in left knee was observed in 12 patients. In DB group, the patients (11 males and 8 females) were aged between 18 and 51 years, with a median age of 26 years. Eight patients showed injuries in right knee and 11 in left knee. The median duration from injury to surgery was 9 days (ranging from 4 to 14) in SB group, and 10 days (5 to 14) in DB group.

This study was approved by the ethic committee of Beijing University of Chinese Medicine Third Affiliated Hospital. Informed consent was signed by every subjects and their guardians before enrollment.

2.1. Surgical procedures

All surgical procedures were performed by the same surgery group with same techniques. STG tendons were harvested with a closed tendon stripper through an anteromedial oblique tibial incision on the medial side of proximal tibia, over the insertion of pes anserinus. The tendons were cleaned from soft tissue. For SB ACL reconstruction, the STG tendons were trimmed into 4, 5, or 6 strands depending on the length and diameter of STG tendons, and the median diameter of grafts was 7.5 mm (6–9 mm). For DB ACL reconstruction, semitendinosus tendon was assembled into 3 or 4 strands used for AM bundle, with a median diameter of 7 mm (6–8 mm), when gracilis tendon was assembled into 3 or 4 strands used for PL bundle, with a median diameter of 6 mm (5–7 mm). The distal free ends of tendon were wove with No.2 braided polyester Syneture TI-CRON (Covidien, Mansfield, MA, USA) through whip-stitch technique. Before graft, an Endobutton CL (Smith & Nephew Endoscopy, Andover, MA, USA) was attached, with a loop length depending on the measurement of tunnel length.

In SB ACL reconstruction, an ACL tibial tunnel director guide (DePuy Mitek, Raynham, MA, USA) set at 55° was introduced through anteromedial portal, and the tip of tibial guide was placed at the center of normal ACL insertion. The position of director guide on tibial cortex was 3 cm medial to tibial tubercle. A tibial tunnel was created with a cannulated drill, reaching a diameter matched to the width of the prepared graft. A Kirschner wire was then drilled into lateral femoral condyle at the center of normal ACL insertion from anteromedial portal, and a femoral tunnel was created with drill system for Endo Button fixation, with a 70° to 80° of knee flexion. The graft was then passed and Endobutton was flipped in a standard fashion for femoral fixation. The knee was rotated from 0° to 120° approximately 25 times for the preconditioning of the graft. The graft was fixed using a bioabsorbable interference screw (ConMed Linvatec, Largo, FL, USA) and a staple at tibial site, with the knee at a 20° flexion with a forced posterior drawer.

For DB ACL reconstruction, the center of AM and PL insertions of ACL in tibia and femur was identified and marked. AM femoral tunnel was drilled at the center of AM insertion with knee at a 95° flexion, and PL femoral tunnel was drilled at the center of PL insertion with knee at a 120° flexion from anteromedial portal. An ACL tibial tunnel director guide (DePuy Mitek) set at 50° was introduced through anteromedial portal. PL tibial tunnel was drilled at the center of PL insertion, and the position of director guide on tibial cortex was 4 cm medial to tibial tubercle. Tibial guide set at 65° was introduced through anteromedial portal, AM tibial tunnel was located at the center of AM insertion, and the position of director guide on tibial cortex was 2 cm medial to tibial tubercle. Each graft was fixed with an Endobutton (Smith & Nephew Endoscopy) at femoral site, and fixed with an absorbable interference screw (ConMed Linvatec) and a staple at tibial site. PL bundle fixation was performed at a 10° knee flexion while AM bundle at a 40° knee flexion, through manual tensioning with a forced posterior drawer.

2.2. Postoperative treatments

The rehabilitation protocol emphasizing early restoration of motion and the improvement of muscle strength was identical for 2 groups. Immediately after surgery, the patients were provided with functional knee brace. Partial weight bearing was permitted with the brace locked in full extension within 4 weeks. ROM was initiated at the fifth week after operation, reaching a 90° flexion within 6 weeks, and full flexion within 8 weeks. After surgery, isometric quadriceps exercises began, aiming to improve muscle strength. Progressive closed-chain exercises were performed after

6 weeks. Full weight bearing with the brace was permitted at the ninth week after operation; full weight bearing without the brace was permitted when sufficient quadriceps strength was regained, approximately at the third month after operation. Walking and swimming were permitted after 3 months, running after 6 months, while contact sport activities or heavy work after 9 months.

2.3. Clinical assessments

The patients' statuses were evaluated between 1 and 2 years after operations to determine functional outcomes for the SB and DB groups. All patients underwent the evaluation through physical examination with Lachman test, pivot shift and valgus laxity test. Manual knee laxity tests for ACL (Lachman test and Pivot-shift test) were graded with normal knee as reference, according to the International Knee Documentation Committee (IKDC) guidelines.[24] Lachman test result was graded as 0 (<3 mm), 1+ (3–5 mm), 2+ (6–10 mm), and 3+ (>10 mm). Pivot-shift phenomenon was graded as 0 (equal), 1+ (glide), 2+ (clunk), and 3+ (gross). Valgus laxity was clinically graded on the basis of medial joint opening which was obtained applying manual valgus stress on knee at a 0° and 30° flexion, respectively.[25] Anterior knee laxity measured with a KT-2000 arthrometer (MEDmetric, San Diego, CA) test at 30 lbs with a 30° knee flexion expressed difference between the injured and uninjured legs. Range of motion was measured and functional evaluation was done using IKDC 2000 and Lysholm scores.

2.4. Statistical analyses

Results were compared between SB and DB groups for preoperative and final follow-up states. Independent-sample *t* test was used to analyze differences in KT-2000 measurement, range of motion, Lysholm and IKDC scores. Differences in results from Lachman test, pivot shift test and manual valgus test were analyzed with Chi Squared test. All statistical analyses were done with SPSS 17.0 (SPSS, Chicago, IL) statistical package and significance level was set at $P<.05$.

3. Results

The median follow-up duration was 15 months (ranging from 11 to 27) in SB group, and 16 months (from 12 to 26) in DB group. At the final follow-up, clinical outcomes estimated via Lachman test, pivot-shift test and manual valgus test were significantly improved, with either SB or DB ACL reconstruction (Table 1, $P<.05$ for all). At the final follow-up, according to pivot shift test, 13 patients (59%) in SB group were at grade 0, 7 (32%) at grade 1, 2 (10%) at grade 2, while none at grade 3. In DB group, 17 patients (89%) were evaluated as grade 0, 2 (11%) as grade 1, while none as grade 2 or 3. The improvement in DB group was better than that in SB group ($P=.029$). Based on Lachman test, 10 cases (45%) were classified into grade 0, 8 (36%) into grade 1, and 4 (18%) into grade 2 in SB group; while no grade 3 cases were observed. In DB group, 13 cases (68%) were at grade 0, 5 (26%) at grade 1, and 1 (5%) at grade 2. Statistical analysis suggested that DB and SB groups exhibited insignificant differences according to Lachman test ($P>.05$). As for valgus knee stability, 17 cases (77%) were categorized into grade 0, 4 (18%) into grade 1, and 1 (5%) into grate 2 in SB group; meanwhile, 16 cases (84%) were at grade 0, and 3 (16%) at grade 1 in DB group. There was no obvious difference between SB and DB groups for valgus tests ($P>.05$) (Table 1). The mean side-to-side differences in patients statuses between 2 groups were significantly decreased at the final follow-up (2.72 mm in SB group, 2.53 mm in DB group) compared to before operation ($P<.001$ for both) (Table 2). There were no significant differences in patients' statuses between SB and DB groups either before operation or at the final follow-up ($P>.05$ for both) (Table 2).

At the final follow-up, the mean extension degree of knee and flexion degree had no significant alterations either in SB or DB group from before operation ($P>.05$ for both). Deficit of extension was 1.8° in SB group and 2.1° in DB group, when deficit of flexion was 2.1° in SB group and 2.5° in DB group. And there were no significant differences between SB and DB groups (Table 3). Lysholm score was significantly elevated at the final follow up in comparison with before operation in both SB and DB groups ($P<.001$ for both). However, no significant differences were observed between SB and DB groups ($P<.05$) (Table 4). IKDC score was distinctly increased at final follow up when compared with before operation in both SB and DB groups ($P<.001$ for both). However, SB and DB techniques did not show significant differences in terms of IKDC scores ($P>.05$ for both) (Table 5).

With regard to complications, 2 patient (9%) in SB group and 3 (16%) patients in DB group showed local tenderness ($P=.513$). Injury of infrapatellar branch of saphenous nerve during the

Table 1

The physical outcomes of the patients in SB (single-bundle) and DB (double-bundle) groups estimated at preoperation and the end of follow-up.

		preoperative				Final follow-up				
		Grade				Grade				
Test	Group	0	1	2	3	0	1	2	3	P^*
Lachman	SB	0	5	14	3	10	8	4	0	<.001
	DB	0	6	10	3	13	5	1	0	.003
	$P^†$	NS				NS				
Pivot-shift	SB	7	10	4	1	13	7	2	0	.028
	DB	6	8	5	0	17	2	0	0	.001
	$P^†$	NS				.029				
Valgus	SB	0	0	22	0	17	4	1	0	<.001
	DB	0	0	19	0	16	3	0	0	<.001
	$P^†$	NS				NS				

* The comparison of physical statuses between preoperation and the end of follow-up in the same group.
† The comparison of physical status between SB and DB groups.

Table 2

Assessment results of KT-2000 arthrometer in SB (single-bundle) and DB (double-bundle) groups.

	SB (n=22) (mm)	DB (n=19) (mm)	P*
Preoperative	6.51±2.05	6.49±1.89	NS
Final follow-up	2.72±0.98	2.53±0.84	NS
P†	<.001	<.001	

* The comparison of physical statuses between preoperation and the end of follow-up in the same group.
† The comparison of physical status between SB and DB groups.
NS = not significant.

harvest of hamstring tendon appeared in 8 (36%) patients of SB group, and 7 (37%) patients of DB group ($P=.975$). Cyclops lesion was not found in either group at the second arthroscopy. There were no infections, deep venous thromboses, or other operative complications in the 2 groups.

4. Discussion

The present study revealed that ACL reconstruction with conservative management of MCL was an effective therapeutic strategy for combined ACL and grade 2 MCL lesions, and that DB ACL reconstruction was superior to SB ACL reconstruction in restoring rotation stability of knee. According to previous reports, conservative management of MCL component and surgical reconstruction of ACL could produce excellent stability and functional outcome for patients suffering from combined ACL-MCL injuries.[10,26,27] In our study, nonoperative management of MCL did not compromise functional or subjective outcome of surgery, and only mild residual medial laxity was found in 8 patients in both groups, which appeared to be asymptomatic.

Some scholars suggested that non-operative treatment should be performed for MCL while reconstruction for ACL when acceptable knee motion has been attained.[16] Delayed ACL reconstruction could reduce the incidence of knee stiffness for these cases.[28,29] In our study, ACL reconstruction was performed, and partial weight bearing was permitted with the brace locked in full extension within 4 weeks to make sure that MCL was completely healed. At the final follow-up, all the patients showed fine motion range of knee in both groups, and their deficits of extension and flexion were not different from those of cases with isolated ACL rupture. Furthermore, early ACL reconstruction could reduce 2 episodes of rehabilitation to 1 and shorten recovery time.

Our findings indicated that DB ACL reconstruction did not produce superior stability for sagittal plane compared with SB ACL reconstruction, which was consistent with results from previous study.[30] Moreover, SB and DB groups showed similar functional outcomes, according to Lachman and valgus tests, KT 2000, ROM, IKDC and Lysholm scores. The findings were in line with those in previous study.[31] In theory, DB ACL reconstruction showed advantages in improving knee rotational instability compared to SB ACL reconstruction.[32] However, pivot-shift test, which is designed to evaluate knee rotational instability in clinic, provided inconsistent evidence in our study. In our study, reconstructed PL-bundle in DB ACL reconstruction could make up some insufficiency caused by MCL injury. This might be the reason why DB ACL reconstruction was superior to SB ACL reconstruction in controlling knee rotational instability.

There were several limitations in the current study. First, the retrospective design might influence the collection of data. Second, the sample size was relatively small that reduced statistical power of our analyses Third, rotational instability and valgus instability were estimated via physical examinations, and pivot-shift and valgus tests were less reproducible and reliable due to subjectivity. Fourth, during the follow-up, independent examiners were not blinded to the purpose of this study. Besides, risk factors inducing surgical complications were not explored in this research. Finally, this was a single-surgery group study, which might limit the generalizability of fine results.

Table 3

The changes of motion (deficit of extension/deficit of flexion) rang in SB (single-bundle) and DB (double-bundle) groups.

	SB (n=22) (°)	DB (n=19) (°)	P*
Preoperative	1.5±0.4/3.0±1.0	1.6±0.6/3.1±0.8	NS/NS
Final follow-up	1.8±0.7/2.1±0.9	2.1±0.5/2.5±0.6	NS/NS
P†	NS/NS	NS/NS	

* The comparison of physical statuses between preoperation and the end of follow-up in the same group.
† The comparison of physical status between SB and DB groups.

Table 4

Lysholm scores of subjects after SB (single-bundle) or DB (double-bundle) ACL reconstruction.

	SB (n=22)	DB (n=19)	P*
Preoperative	51.6±7.8	52.3±9.4	NS
Final follow-up	91.3±5.4	93.1±4.9	NS
P†	<.001	<.001	

* The comparison of physical statuses between preoperation and the end of follow-up in the same group.
† The comparison of physical status between SB and DB groups.

Table 5

IKDC 2000 scores of subjects before operation and at final follow up.

	SB (n=22)	DB (n=19)	P*
Preoperative	61.6±8.5	64.3±7.5	NS
Final follow-up	89.8±5.4	90.5±6.3	NS
P†	<.001	<.001	

* The comparison of physical statuses between preoperation and the end of follow-up in the same group.
† The comparison of physical status between SB and DB groups.
IKDC = International Knee Documentation Committee, SB = single-bundle, DB = double-bundle, NS = not significant.

5. Conclusion

ACL reconstruction with conservative management of MCL in patients with combined ACL and grade 2 MCL lesions could provide satisfying outcomes. DB ACL reconstruction is superior to SB ACL reconstruction in controlling rotational instability of knee, but shows no significant difference in Lachman and valgus tests, KT 2000, range of motion, IKDC or Lysholm scores from SB strategy.

Author contributions

Data curation: Lian-Xu Chen.
Formal analysis: Lian-Xu Chen.

Funding acquisition: Lian-Xu Chen.
Investigation: Lian-Xu Chen.
Methodology: Lian-Xu Chen.
Resources: Hong-Hong Wang.
Software: Hong-Hong Wang.
Writing – original draft: Hong-Hong Wang.
Writing – review & editing: Hong-Hong Wang.

References

[1] Pandey V, Khanna V, Madi S, et al. Clinical outcome of primary medial collateral ligament-posteromedial corner repair with or without staged anterior cruciate ligament reconstruction. Injury 2017;48:1236–42.
[2] Yuuki A, Muneta T, Ohara T, et al. Associated lateral/medial knee instability and its relevant factors in anterior cruciate ligament-injured knees. J Orthop Sci 2017;22:300–5.
[3] Dale KM, Bailey JR, Moorman CT. Surgical management and treatment of the anterior cruciate ligament/medial collateral ligament injured knee. Clin Sports Med 2017;36:87–103.
[4] Westermann RW, Spindler KP, Huston LJ, et al. Outcomes of grade III medial collateral ligament injuries treated concurrently with anterior cruciate ligament reconstruction: a multicenter study. Arthroscopy 2019;35:1466–72.
[5] Vermeijden HD, Jonkergouw A, van der List JP, et al. The multiple ligament-injured knee: when is primary repair an option? Knee 2020; 27:173–82.
[6] Snaebjornsson T, Hamrin Senorski E, Svantesson E, et al. Graft fixation and timing of surgery are predictors of early anterior cruciate ligament revision: a cohort study from the swedish and norwegian knee ligament registries based on 18,425 patients. JB JS Open Access 2019;4:e0037.
[7] Yan W, Xu X, Xu Q, et al. In vivo gait kinematics of the knee after anatomical and non-anatomical single-bundle anterior cruciate ligament reconstruction-a prospective study. Ann Transl Med 2019;7:799.
[8] Tandogan NR, Kayaalp A. Surgical treatment of medial knee ligament injuries: current indications and techniques. EFORT Open Rev 2016; 1:27–33.
[9] Grant JA, Tannenbaum E, Miller BS, et al. Treatment of combined complete tears of the anterior cruciate and medial collateral ligaments. Arthroscopy 2012;28:110–22.
[10] Gallo RA, Kozlansky G, Bonazza N, et al. Combined anterior cruciate ligament and medial collateral ligament reconstruction using a single achilles tendon allograft. Arthrosc Tech 2017;6:e1821–7.
[11] Mancini EJ, Kohen R, Esquivel AO, et al. Comparison of ACL strain in the MCL-deficient and MCL-reconstructed knee during simulated landing in a cadaveric model. J Sports Med 2017;45:1090–4.
[12] Ahn JH, Lee SH. Risk factors for knee instability after anterior cruciate ligament reconstruction. Knee Surg Sports Traumatol Arthrosc 2016;24:2936–42.
[13] Georgiev GP, Kotov G, Iliev A, et al. Comparison between operative and non-operative treatment of the medial collateral ligament: histological and ultrastructural findings during early healing in the epiligament tissue in a rat knee model. Cells Tissues Organs 2018;206:165–82.
[14] Georgiev GP, Iliev A, Kotov G, et al. Epiligament tissue of the medial collateral ligament in rat knee joint: ultrastructural study. Cureus 2019;11:e3812.
[15] Georgiev GP, Landzhov B, Kotov G, et al. Matrix metalloproteinase-2 and -9 expression in the epiligament of the medial collateral and anterior cruciate ligament in human knees: a comparative study. Cureus 2018;10: e3550.
[16] Blanke F, Paul J, Haenle M, et al. Results of a new treatment concept for concomitant lesion of medial collateral ligament in patients with rupture of anterior cruciate ligament. J Knee Surg 2017;30:652–8.
[17] Chen W, Li H, Chen Y, et al. Bone-patellar tendon-bone autografts versus hamstring autografts using the same suspensory fixations in ACL reconstruction: a systematic review and meta-analysis. Orthop J Sports Med 2019;7:2325967119885314.
[18] Han JK, Chun KC, Lee SI, et al. Comparison of modified transtibial and anteromedial portal techniques in anatomic single-bundle ACL reconstruction. Orthopedics 2019;42:83–9.
[19] Naghibi H, Janssen D, Van Tienen T, et al. A novel approach for optimal graft positioning and tensioning in anterior cruciate ligament reconstructive surgery based on the finite element modeling technique. Knee 2020.
[20] Tejpal T, Gupta A, Shanmugaraj A, et al. Anteromedial portal double-bundle anterior cruciate ligament reconstruction yields similar outcomes to Non-AMP femoral drilling double-bundle techniques: a systematic review of comparative studies. Orthop J Sports Med 2019;7: 2325967119888140.
[21] Janko M, Verboket RD, Plawetzki E, et al. Comparable results after arthroscopic replacement of the anterior cruciate ligament: clinical and functional results after single bundle and double bundle reconstruction. Der Chirurg 2020;91:67–75.
[22] Mayr HO, Benecke P, Hoell A, et al. Single-bundle versus double-bundle anterior cruciate ligament reconstruction: a comparative 2-year follow-up. Arthroscopy 2016;32:34–42.
[23] Sakamoto Y, Tsukada H, Sasaki S, et al. Effects of the tibial tunnel position on knee joint stability and meniscal contact pressure after double-bundle anterior cruciate ligament reconstruction. J Orthop Sci 2020.
[24] Jia ZY, Zhang C, Zou Y, et al. Translation and validation of the simplified Chinese version of international knee documentation committee subjective knee form. Arch Orthop Trauma Surg 2018; 138:1433–41.
[25] Putman S, Ehlinger M, Tillie B, et al. Total knee replacement on more than 20 degrees valgus: a case control study. Orthopaedics Traumatol Surg Res 2019;105:613–7.
[26] Zhang H, Sun Y, Han X, et al. Simultaneous reconstruction of the anterior cruciate ligament and medial collateral ligament in patients with chronic ACL-MCL lesions: a minimum 2-year follow-up study. Am J Sports Med 2014;42:1675–81.
[27] Papalia R, Osti L, Del Buono A, et al. Management of combined ACL-MCL tears: a systematic review. Br Med Bull 2010;93:201–15.
[28] Matthewson G, Kooner S, Rabbani R, et al. Does a delay in anterior cruciate ligament reconstruction increase the incidence of secondary pathology in the knee? A systematic review and meta-analysis. Clin J Sport Med 2019.
[29] Grassi A, Kim C, Marcheggiani Muccioli GM, et al. What is the mid-term failure rate of revision ACL reconstruction? A systematic review. Clin Orthop Relat Res 2017;475:2484–99.
[30] Chen H, Chen B, Tie K, et al. Single-bundle versus double-bundle autologous anterior cruciate ligament reconstruction: a meta-analysis of randomized controlled trials at 5-year minimum follow-up. J Orthop Surg Res 2018;13:50.
[31] Dong Z, Niu Y, Qi J, et al. Long term results after double and single bundle ACL reconstruction: Is there any difference? A meta - analysis of randomized controlled trials. Acta Orthop Traumatol Turc 2019; 53:92–9.
[32] Sernert N, Hansson E. Similar cost-utility for double- and single-bundle techniques in ACL reconstruction. Knee Surg Sports Traumatol Arthrosc 2018;26:634–47.