2019 SCIENCELINE
Journal of Life Science and Biomedicine
J Life Sci Biomed, 9 (4): 109-116, 2019

ISSN 2251-9939

Comparative study of two methods of anterior cruciate ligament reconstruction with lavsan (polyethylene terephthalate)

Murodjon Ergashevich IRISMETOV, Farrukh Makhamadjonovich USMONOV✉, Dilshod Fayzakhmatovich SHAMSHIMETOV, Alisher Mukhammadjonovich KHOLIKOV, Kurbon Nurmamatovich RAJABOV, Murodjon Bakhodirovich TADJINAZAROV

Department of Sports Traumatology, Republican Specialized Scientific and Practical Medical Centre of Traumatology and Orthopaedics Uzbekistan, Tashkent

✉Corresponding author's Email: farruhtravm@rambler.ru

ABSTRACT

Introduction. The anterior cruciate ligament (ACL) is one of the main stabilizateur of the knee joint. Many methods were suggested for its reconstruction with different allo/autografts, as well as synthetic materials. Aim. The study aimed to compare two methods of ACL reconstruction with lavsan (polyethylene terephthalate). Methods. The study included 102 patients who underwent ACL reconstruction with lavsan tape (polyethylene terephthalate). Group 1 (46 patients) underwent single-bundle ACL reconstruction, and group 2 (56 patients) underwent double-bundle reconstruction. Patients were evaluated with Lachman, anterior drawer and pivot-shift tests and Lysholm score. Results. Our results showed better results in double-bundle group, especially rotational stability was significant better. Besides that majority of patients of I group had some problem flexion of the operated knees. Conclusion. Independent of the method of ACL reconstructions these surgeries must be perform taking into account anatomic features and changes of the knee. Double-bundle technique of ACL reconstruction with lavsan provides better stability than single-bundle technique.

Original Article

PII: S225199391900017-9

Rec. 15 June 2019
Rev. 22 July 2019
Pub. 25 July 2019

Keywords
Anterior Cruciate Ligament, Single-Bundle Technique, Double-Bundle-Technique, Synthetic Material

Abbreviations: ACL: Anterior cruciate ligament, BTB: Bone-tibia-bone, LARS: Ligament advanced reinforcement system, AM: Antero-medial, PL: Postero-lateral

INTRODUCTION

Anterior cruciate ligament is one of the stabilizing structures of the knee. The incidence of ACL ruptures increased in recent times, and today ACL reconstruction is one of most frequently performed surgeries in orthopaedics [1]. ACL ruptures may lead instability of the knee which results in disability of the knee in cutting and pivoting activities [2]. Unstable knee after ACL ruptures result in following meniscus injuries, degenerative changes of articular surfaces of knee [2, 3]. The goal of ACL reconstruction is stabilization of the knee; minimize risk factors of the risk of re-injury, to return previous activity of sportsmen. At present time, single and double-bundle methods of ACL reconstruction are used. Each technique has its indications and contraindications [2]. It is necessary to take into account anatomic and individual characteristics of the patient to choose a method of surgery.

A single-bundle ACL reconstruction means to restore the native anatomy of ACL as closely as possible and to achieve normal knee biomechanics [2]. In order to achieve it is necessary to follow the following principles: 1) to observe and to objectify native anatomy of patients; 2) to individualize each surgery according patient's anatomy; 3) to place the tunnels and grafts at in the centre of patient's footprints; 4) to re-establish knee biomechanics by tensioning of the graft. In this method femoral and tibial tunnels must be positioned midway between the centres of AM and PL insertion sites.

Double-bundle reconstruction of ACL is explained with anatomic structure of ACL. ACL consists of two parts: antero-medial (AM) and postero-lateral (PL) bundles [1]. Both bundles are synergists but in different position of the knee they have different functions. Insufficiency of AM bundle shows increased antero-posterior translation of the tibia like in complete ACL rupture. Insufficiency of PL bundle results in instability with pivoting and turning. In double-bundle ACL reconstruction AM and PL tunnels are drilled separately at the

native femoral and tibial sites. In both methods femoral tunnels can be drilled with using a transtibial or medial portal technique [1, 2]. Double-bundle reconstruction of ACL introduced to achieve better stability, particularly more stability for rotator loads [4, 5]. Some studies demonstrated that inability of single bundle reconstruction to restore intact knee rotational stability [1]. But there are studies that don't show differences between a single-bundle and double-bundle technique, when placed anatomically and customized to the patient's anatomy [6-9].

Despite at present time ACL reconstruction with auto- and allografts is popular, synthetic artificial ligaments are still used [3]. One of them is polyethylene terephthalate (lavsan), there are many reports about ACL reconstruction with this artificial ligament. Lavsan is a non-absorable synthetic material containing polyethylene terephthalate fibres [10]. The use of artificial ligaments based on lack of donor comorbidity, reduced operation time, abundant supply and enough strength and early loading of the operated extremity that result in shortening of rehabilitation period [3, 11-13]. Parchi et al. [14] proposed the use of a synthetic graft for the ACL reconstruction to all patients older than 30 years with a symptomatic isolated ACL injury in order a quick return to their previous sport activity level as a possible alternative to the autograft. Pan et al. [15] reported about the similar results obtained at midterm follow-up in groups between bone –patellar-bone (BTB) and LARS groups. Huang et al. [13] concluded that the LARS® artificial ligament has excellent biomechanical properties in comparing with autologous and allogenic tendons that means LARS artificial ligament can be widely used for ACL reconstruction. Therefore, the aim of study was to compare two methods of ACL reconstruction with lavsan (polyethylene terephthalate).

MATERIAL AND METHODS

Our study was included 102 patients with ACL rupture who underwent ACL reconstruction with synthetic material (lavsan tape). Assessment was made with Lachman, anterior drawer and pivot-shift tests and Lysholm knee scoring scale. First group included 46 patients (42 male, 4 female) who underwent single-bundle (SB) technique. Lachman test was positive in all patients of this group: 3-5 mm (n=32), 6-10 mm (n=14). Anterior drawer test was negative in 4 patients, positive 3-5 mm (n=32), 6-10 mm (n=10). Pivot shift was negative in 18 patients, positive 1+ (n=20), positive 2+ (n=8). A mean Lysholm score on this scale ranged was 57 to 72 points (mean 64 points). Second group included 56 patients (49 male and 7 female), who underwent ACL reconstruction with double-bundle (DB) technique. Lachman test was positive in all patients of this group: 3-5 mm (n=42), 6-10 mm (n=16). Anterior drawer test was negative in 8 patients, positive 3-5 mm (n=41), 6-10 mm (n=7). Pivot shift test was negative in 8 patients, positive 1+ (n=35), positive 2+ (n=13). A mean score on Lysholm scale ranged from 55 to 74 points (mean 62 points).

The aim was to compare results of both techniques of ACL reconstruction that are made under spinal anesthesia in supine position of patient. Surgeries were performed by different doctors of the same department who were masters of arthroscopic surgery. An arthroscope is inserted inside of the knee with using routine anterolateral and anteromedial portals. First all knee structures is inspected carefully, including meniscus, articular cartilage, synovial membrane. In case of meniscus tear the torn part of meniscus is resected. Then ACL reconstruction is performed using single- or double-bundle technique depending on patient's conditions, anatomy and individual parameters.

Single-bundle technique of ACL reconstruction with lavsan tape

After arthroscopically revealing ACL rupture the knee is flexed to 110° and a femoral tunnel is drilled at centre of insertion site of ACL using an anteromedial portal technique. First it is drilled with guide pin, then with drill diameter of 4 mm along the whole lateral condyle of the femur.

After that knee flexed under 90° and the tip of the conductor is put to the insertion site of the centre of ACL. A conductor is placed on 45-50° to the articular surface of plateau of the tibia, approximately 3.5-4 cm medially from the tibial tuberosity. On this area an incision of 1.5 cm length is made. First it is drilled with a guide pin from this incision inside of the knee, and then the tunnel is drilled with a drill of 4 mm diameter. After drilling tunnels, first end of the lavsan tape of 5 mm width is passed first to the tibial and femoral tunnels respectively. The end of the lavsan tape is pulled out outside of lateral condyle of the femur, length of pulled out tape must be minimum 5 cm of length. Then 2 cm incision is made of medial condyle area, just near the insertion site of the medial collateral ligament to the femur. A surgical clamp is inserted from this incision between joint capsule and fascia, and directed distally, that is to the 1.5 mm sized incision on the anteromedial part of proximal tibia. Then the second end of the lavsan tape is fixed with a surgical clamp and pulled out from the incision on medial condyle of the femur.

Drilling of transversal tunnel in the femur

Then it is drilled a transversal tunnel with a guide wire from the medial condyle to the lateral condyle of the femur. After that it is drilled with 4 mm drill of diameter. Second end of the lavsan is passed from the transversal tunnel (from medial the condyle to the lateral condyle) and pulled out on the lateral femoral condyle area. Length of the free end of the lavsan tape must have 5 cm from a skin. The scheme of surgery is prescribed on figure 1.

After pulling out of both ends of lavsan tape, 3 cm sized incision is made above on lateral femoral condyle between both ends of the lavsan tape. Both ends are pulled out from this incision, soft tissues separated till the bone tissues and are tied into a knot (Figure 2). The extra ends of the lavsan tape above the knot are cut. Drainage of wounds is made, sutures is put. Aseptic bandages. MRI is made after surgery (Figures 3 and 4).

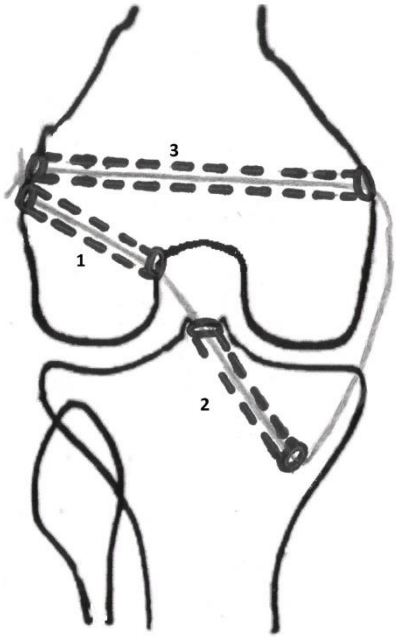

Figure 1. The scheme of single bundle ACL reconstruction with lavsan tape.

Figure 2. A) Pulling out of both ends of the lavsan tape from the same incision; B) Knotting of both ends of lavsan tapes.

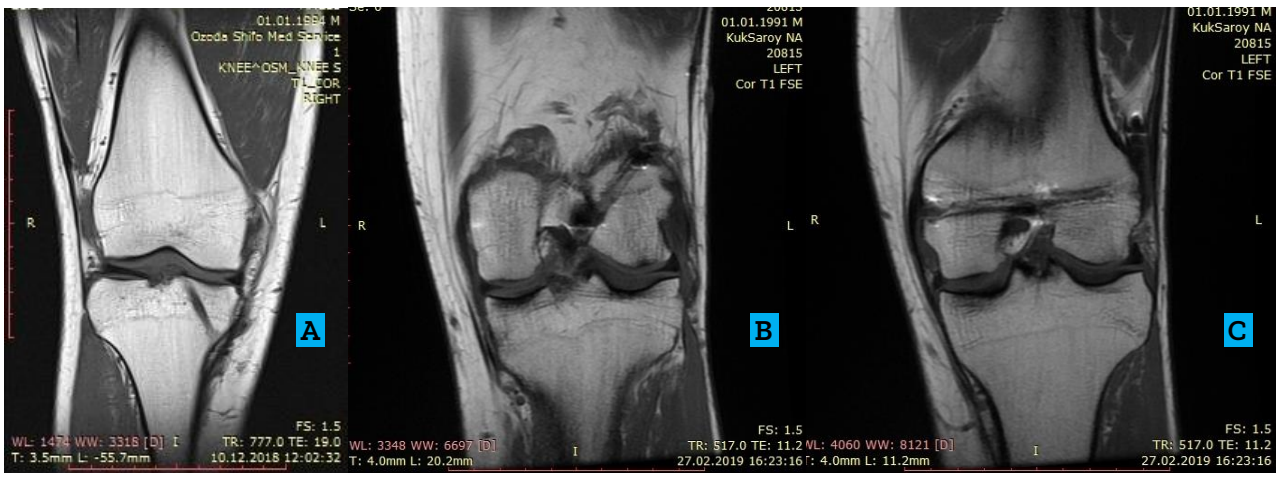

Figure 3. MRI of patient after surgery. A) tibial tunnel on the right tibia;B) femoral tunnel of the left femur;C) transversal tunnel of femur of left femur.

Figure 4. MRI of patient in 18 month after single-bundle ACL reconstruction technique. It is seen a ligamentization of the lavsan tape (yellow arrow) and a hole of the transversal tunnel in the femur (white arrow).

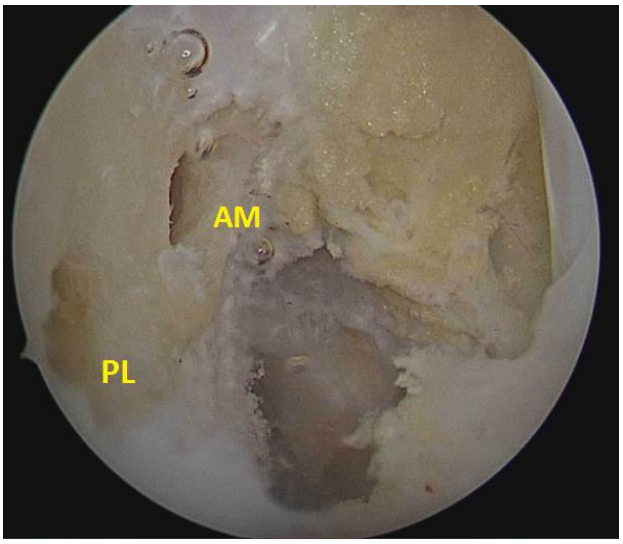

Figure 5. Arthroscopic view of drilled femoral tunnels. AM: anteromedial tunnel, PM: posterolateral tunnel.

Double-bundle technique of ACL reconstruction with lavsan tape

The same arthroscopic portals are used for double-bundle technique. After arthroscopically revealing of ACL rupture the knee is flexed to 110° and two femoral tunnels is drilled at insertion sites of both bundles of ACL. First tunnel is drilled at insertion site of PL (posterolateral) bundle of ACL. It is drilled with guide pin first, then with drill diameter of 4 mm along the whole lateral condyle of the femur. In order to make the second tunnel a drill bit put to the insertion site of AM (anteromedial) bundle and it is drilled with guide pin first, then with drill diameter of 4 mm along the whole lateral condyle of the femur (Figure 5). After that knee flexed under 90° and the tip of the conductor is put to the insertion site of PL bunble of ACL at tibia. Conductor is placed on 45-50° to the articular surface of plateau of the tibia, approximately 3.0-4 cm medially from the tibial tuberosity. It is drilled with guide pin first, then with drill diameter of 4 mm from outside to inside (tunnel 3). Then the tip of the conductor is put to the insertion site of AM bunble of ACL at tibia. The conductor is placed on 60-65° to the articular surface of plateau of the tibia, approximately 1.5-2 cm medially from the tibial tuberosity. It is drilled with guide pin first, then with drill diameter of 4 mm from outside to inside (tunnel 4). After drilling tunnels, one end of the lavsan tape of 5 mm width is inserted first to the tunnel 3 (PL tunnel of tibia), then tunnel 1 1-tunnel (PL tunnel of femur) respectively. End of the lavsan tape is pulled out outside with minimum 5 cm length on lateral condyle of femur. Second end of the lavsan tape is inserted first tunnel 4 and tunnel 2 respectively (AM tunnels of tibia and femur respectively), then this second end is pulled out on the lateral condyle of femur with minimum 5 cm length on lateral condyle of femur. After pulling out of lavsan tapes 3.0 cm sized incision is made above on lateral femoral condyle (the scheme of double-bundle-technique is prescribed on figure 6). Both ends of the lavsan tape are pulled out from this incision and tied into a knot (Figure 2). The extra ends of the lavsan tape above the knot are cut. Drainage of wounds is made, sutures is put. Aseptic bandages. With this way AM and PL bundles of ACL is created with a lavsan tape (Figure 7). MRI is done after surgery (Figure 8).

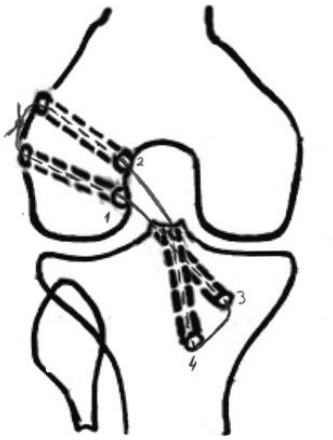

Figure 6. Scheme of double-bundle ACL reconstruction. 1) PL tunnel in the femur, 2) AMtunnel in the femur, 3) PL tunnel in the tibia, 4) AM tunnel in the tibia.

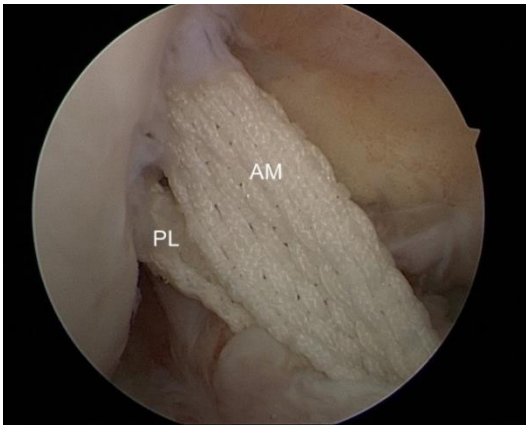

Figure 7. Arthroscopic view after double-bundle ACL reconstruction with lavsan tape. AM: anteromedial bundle, PL: posterolateral bundle.

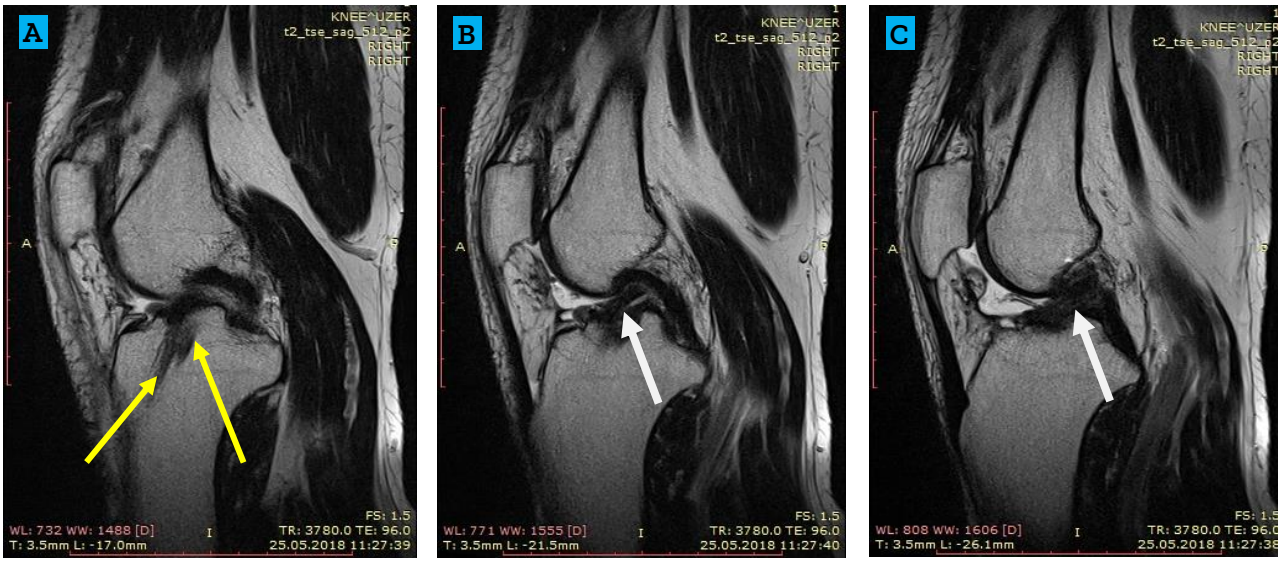

Figure 8. MRI of patient with double-bundle technique in 1 year after surgery. A) drilled femoral tunnels (yellow arrows). B, C). Ligamentization of lavsan tape is seen (white arrow).

Postoperative treatment is done by a standard management of ACL reconstructed patients. Plaster cast was put to the operated extremity for 10-12 days period. In order to prevent hemarthrosis and swelling ice packs were put regularly 10-15 minutes per hour to operated knees up to 10-12 days. From the next day of surgery isometric exercises of the knee were recommended to prevent hypotrophy of muscles. Medications (antibiotics, anticoagulants, anti-inflammation remedies and etc.) are recommended following standards of treatment. Walking was permitted from the next day of surgery with crutches till 4 weeks. In 10-12 days plaster cast is removed and passive range of motions in the knee (flexion, extension) are recommended. Strengthening exercises of quadriceps muscle are recommended step by step. Return to sport is recommended from 6-9 month after surgery, depending on condition of patients.

Ethical approval

The review board and ethics committee of Republican Specialized Scientific and Practical Medical Centre of Traumatology and Orthopaedics Uzbekistan approved the study protocol and informed consents were taken from all the participants.

RESULTS

All patients were followed up at 14-18 month period. At follow up period all patients of both group felt the state of their knees to become better. No major complications occurred as well as venous thrombosis, pulmonary embolism, intra-articular infection in both groups. Lachman, anterior drawer and pivot-shift tests were checked at follow up and patients accessed with Lysholm score. Concerning results of antero-posterior stability results were better in group 2. Lysholm score was higher in group 2 in compared to group 1. Concerning of pivot shift test better results achieved in group 2.

Group 1. Lachman test was negative in 39 patients, slightly positive up to 3 mm in 7 patients. Anterior drawer test was negative in 42 patients and slightly positive up to 3 mm in 4 patients. Pivot-shift test was negative in 39 patients, slightly positive 1+ in 7 patients. A mean Lysholm score was grown up to 82 (ranged between 74 to 92).

Group 2. Lachman test was negative in 50 patients, slightly positive up to 3 mm in 6 patients. Anterior drawer test was negative in 53 patients and slightly positive up to 3 mm in 3 patients. Pivot-shift test was negative in all 56 patients. A mean Lysholm score was grown up to 90 (ranged between 86 to 94).

Patients with of 1-group had difficulty with increasing of motions of the knee. 7 patients of the 1-group had knee flexion deficit approximately 15-20°, while 2 patient of 2-group had knee flexion deficit who has osteoarthritic changes (Figure 9). Synovitis occurred in 6 patients (3 patients from group 1, 3 patients from group 2) till 2-3 months period after surgery. Synovitis was successfully treated with anti-inflammation remedies, ice packs, antibiotics, and intra-articular glucocorticosteroids.

Table 1. Results of treatment of ACL reconstruction of both groups

Groups		Lachman test			Anterior drawer test			Pivot shift test		
		Negative	3-5 mm	6-10 mm	Negative	3-5 mm	6-10 mm	Negative	+	++
Group 1	Preop: Before surgery	-	32	14	4	32	10	18	20	8
	Postop: After surgery	39	7	-	42	4	-	39	7	-
Group 2	Preop: Before surgery	-	39	17	8	41	7	8	35	13
	Postop: After surgery	50	6	-	53	3	-	56	-	-

Figure 9. Range of motions after surgery. A) Patient in 18 motnth after singe- boundle ACL reconstruction with lavsan. There is knee flexion deficit for 20 dg. B) Patient in 12 month after double- boundle lavsanoplasty. No restriction of range of motions.

DISCUSSION

Many studies showed that results of ACL reconstruction with artificial ligaments were successful [3, 15-17]. Krudwig [12] reported about good results in patients with their satisfaction and anteroposterior stability in patients with artificial Trevira-Hofest devices. Lavoi et al. [18] reported about good clinical results with using LARS artificial ligament at 8-45 follow up in 47 patients. But there are many reports about complications of artificial ligament (tear, foreign-body reactions, synovitis, recurrent instability) [11, 19, 20-22]. Gao et al. [23] reported about developed only one case of synovitis (from 159 patients) with overall complications rate 5,7% after ACL reconstruction with LARS in his a multicenter study in with 3- to 5-year follow up.

In our study we watched synovitis in a few patients, who were prescribed medications and ice packages, in severe synovitis we used puncture of the operated knee with administering glucocorticosteroids. Our patients of 1-group felt pain and difficulties during active flexion of operated knee, especially flexion after 90 dg. It is explained with a non-anatomical position of the second end of lavsan tape. Perhaps, direction of the second end of a lavsan tape carried from the medial part of proximal tibia and its transversal direction from the medial condyle to the lateral condyle bothered to achieve full range of motion of the knee.

Struewer et al. [17] and Lee et al. [24] reported about synovial coverage of grafts during second look arthroscopy after ACL reconstruction with augmentation with an artificial ligament. Despite we did not perform second look arthroscopy we watched a ligamentization of artificial grafts in MRI made after at least a year after surgery in both methods.

It is necessary to take into account details, which depends also on human factor. There are two problems which affects the functional outcome of primary ACL reconstruction. First is a correct femoral and tibial tunnel placement. If drill the tunnel too anteriorly on the femoral condyle it may lead to reduced knee flexion and instability of the knee. If drill the tunnel too posteriorly on the lateral femoral condyle it may lead to reduced extension.

Second is a persisting instability after single-bundle ACL reconstruction [1]. ACL reconstruction focused only AM bundle reconstruction ignoring PL bundle leads to rotational instability. It is necessary to take attention that pivot-shift test is not objective but subjective assessment, it is done manually. The speed of the procedure, a magnitude of force applied to the knee and the abduction angle of the hip depends on examiner [25]. Several studies showed that there are not significant differences of results between single-and double-bundle technique when the graft placed anatomically [7, 8].

CONCLUSION

Our study showed that double-bundle reconstruction of ACL with lavsan provided better results than single-bundle technique. It was seen especially in rotational stability. Besides that there were not problems of double-bundle group with restricting of range of motions of operated knee. In choose ACL reconstruction technique it is necessary to take into account anatomic features and changes of the knee. Thus, on method of ACL reconstruction: single-bundle or double-bundle technique, surgery should be performed according an anatomic double-bundle structure of ACL.

DECLARATIONS

Acknowledgements

This work was supported by, Republican Specialized Scientific and Practical Medical Centre of Traumatology and Orthopaedics Uzbekistan, Tashkent, Uzbekistan

Authors' Contributions

All authors contributed equally to this work.

Competing interests

The authors declare that they have no competing interests.

REFERENCES

1. Zhu W, Lu W, Han Y, Hui S, Ou Y, Peng L, Fen W, Wang D, Zhang L, Zeng Y. Application of a computerised navigation technique to assist arthroscopic anterior cruciate ligament reconstruction. International Orthopaedics. 2013 Feb 1;37(2):233-8. Google Scholar ; https://doi.org/10.1007/s00264-012-1764-6
2. Muller B, Hofbauer M, Wongcharoenwatana J, Fu FH. Indications and contraindications for double-bundle ACL reconstruction. International Orthopaedics. 2013 Feb 1;37(2):239-46. Google Scholar ; https://doi.org/10.1007/s00264-012-1683-6
3. Machotka Z, Scarborough I, Duncan W, Kumar S, Perraton L. Anterior cruciate ligament repair with LARS (ligament advanced reinforcement system): a systematic review. BMC Sports Science, Medicine and Rehabilitation. 2010 Dec; 2(1):29. doi: 10.1186/1758-2555-2-29. Google Scholar ; https://doi.org/10.1186/1758-2555-2-29
4. Siebold R, Dehler C, Ellert T. Prospective randomized comparison of double-bundle versus single-bundle anterior cruciate ligament reconstruction. Arthroscopy: The Journal of Arthroscopic & Related Surgery. 2008 Feb 1;24(2):137-45. Google Scholar ; https://doi.org/10.1016/j.arthro.2007.11.013
5. Zaffagnini S, Bruni D, Muccioli GM, Bonanzinga T, Lopomo N, Bignozzi S, Marcacci M. Single-bundle patellar tendon versus non-anatomical double-bundle hamstrings ACL reconstruction: a prospective randomized study at 8-year minimum follow-up. Knee Surgery, Sports Traumatology, Arthroscopy. 2011 Mar 1;19(3):390-7. 19:390-397. Google Scholar ; https://doi.org/10.1007/s00167-010-1225-y

6. Streich NA, Friedrich K, Gotterbarm T, Schmitt H. Reconstruction of the ACL with a semitendinosus tendon graft: a prospective randomized single blinded comparison of double-bundle versus single-bundle technique in male athletes. Knee Surgery, Sports Traumatology, Arthroscopy. 2008 Mar 1;16(3):232-8. Google Scholar ; https://doi.org/10.1007/s00167-007-0480-z

7. Hussein M, van Eck CF, Cretnik A, Dinevski D, Fu FH. Prospective randomized clinical evaluation of conventional single-bundle, anatomic single-bundle, and anatomic double-bundle anterior cruciate ligament reconstruction: 281 cases with 3-to 5-year follow-up. Am J Sports Med, 2012 Mar;40(3):512-20. Google Scholar ; https://doi.org/10.1177/0363546511426416

8. Hussein M, van Eck CF, Cretnik A, Dinevski D, Fu FH. Individualized anterior cruciate ligament surgery: a prospective study comparing anatomic single-and double-bundle reconstruction. Am J Sports Med, 2012 Aug;40(8):1781-8. Google Scholar ; https://doi.org/10.1177/0363546512446928

9. Li X, Xu CP, Song JQ, Jiang N, Yu B. Single-bundle versus double-bundle anterior cruciate ligament reconstruction: an up-to-date meta-analysis. International orthopaedics. 2013 Feb 1;37(2):213-26. Google Scholar ; https://doi.org/10.1007/s00264-012-1651-1

10. Newman SD, Atkinson HD, Willis-Owen CA. Anterior cruciate ligament reconstruction with the ligament augmentation and reconstruction system: a systematic review. Int Orthop. 2013 Feb;37(2):321-6. PubMed PMID: 22976593; PubMed Central PMCID: PMC3560896 ; https://doi.org/10.1007/s00264-012-1654-y

11. Boszotta H, Helperstorfer W, Pflanzl W. Foreign body synovitis--a limiting factor in use of the Trevira ligament in cruciate ligament surgery?. Unfallchirurgie. 1993 Jun; 19(3):138-43. Google Scholar ; https://doi.org/10.1007/BF02588036

12. Krudwig WK. Anterior cruciate ligament reconstruction using an alloplastic ligament of polyethylene terephthalate (PET–Trevira®–hochfest). Follow-up study. Biomed Mater Eng, 2002 Jan 1;12(1):59-67. Google Scholar ;

13. Huang JM, Qian WA, Feng SH, Wang ZM, Kang YF. Cruciate ligament reconstruction using LARS artificial ligament under arthroscopy: 81 cases report. Chinese Med J. 2010 Jan 1;123(2):160-4. Google Scholar

14. Parchi PD, Ciapini G, Paglialunga C, Giuntoli M, Picece C, Chiellini F, Lisanti M, Scaglione M. Anterior cruciate ligament reconstruction with LARS artificial ligament—clinical results after a long-term follow-up. Joints. 2018 Jun; 6(02):075-9. 6(2):75-79. Search Google Scholar ; https://doi.org/10.1055/s-0038-1653950

15. Pan X, Wen H, Wang L, Ge T. Bone–patellar tendon–bone autograft versus LARS artificial ligament for anterior cruciate ligament reconstruction. Eur J Orthop Surg Traumatol, 2013 Oct 1;23(7):819-23. Google Scholar ; https://doi.org/10.1007/s00590-012-1073-1

16. Nau T, Lavoie P, Duval N. A new generation of artificial ligaments in reconstruction of the anterior cruciate ligament: two-year follow-up of a randomised trial. J Bone Joint Surg Br, 2002 Apr;84(3):356-60. Google Scholar ; https://doi.org/10.1302/0301-620X.84B3.0840356

17. Struewer J, Ziring E, Ishaque B, Efe T, Schwarting T, Buecking B, Schüttler KF, Ruchholtz S, Frangen TM. Second-look arthroscopic findings and clinical results after polyethylene terephthalate augmented anterior cruciate ligament reconstruction. International orthopaedics. 2013 Feb 1;37(2):327-35. Google Scholar ; https://doi.org/10.1007/s00264-012-1652-0)

18. Lavoie P, Fletcher J, Duval N. Patient satisfaction needs as related to knee stability and objective findings after ACL reconstruction using the LARS artificial ligament. The knee. 2000 Jul 1;7(3):157-63. Google Scholar ; https://doi.org/10.1016/S0968-0160(00)00039-9

19. Barrett GR, Line JR LL, Shelton WR, Manning JO, Phelps R. The Dacron ligament prosthesis in anterior cruciate ligament reconstruction: A four-year review. Am J Sports Med, 1993 May;21(3):367-73. Google Scholar ; https://doi.org/10.1177/036354659302100307

20. Ventura A, Terzaghi C, Legnani C, Borgo E, Albisetti W. Synthetic grafts for anterior cruciate ligament rupture: 19-year outcome study. The Knee. 2010 Mar 1;17(2):108-13. Google Scholar ; https://doi.org/10.1016/j.knee.2009.07.013

21. Olson EJ, Kang JD, Fu FH, Georgescu HI, Mason GC, Evans CH. The biochemical and histological effects of artificial ligament wear particles: in vitro and in vivo studies. Am J Sports Med, 1988 Nov;16(6):558-70. Google Scholar ; https://doi.org/10.1177/036354658801600602

22. Ishibashi Y, Toh S, Okamura Y, Sasaki T, Kusumi T. Graft incorporation within the tibial bone tunnel after anterior cruciate ligament reconstruction with bone-patellar tendon-bone autograft. Am J Sports Med, 2001 Jul;29(4):473-9. Google Scholar ; https://doi.org/10.1177/03635465010290041601

23. Gao K, Chen S, Wang L, Zhang W, Kang Y, Dong Q, Zhou H, Li L. Anterior cruciate ligament reconstruction with LARS artificial ligament: a multicenter study with 3-to 5-year follow-up. Arthroscopy: The Journal of Arthroscopic & Related Surgery. 2010 Apr 1;26(4):515-23. Google Scholar ; https://doi.org/10.1016/j.arthro.2010.02.001

24. Lee JH, Bae DK, Song SJ, Cho SM, Yoon KH. Comparison of clinical results and second-look arthroscopy findings after arthroscopic anterior cruciate ligament reconstruction using 3 different types of grafts. Arthroscopy: The Journal of Arthroscopic & Related Surgery. 2010 Jan 1;26(1):41-9. Google Scholar ; https://doi.org/10.1016/j.arthro.2009.06.026

25. Legnani C, Ventura A, Terzaghi C, Borgo E, Albisetti W. Anterior cruciate ligament reconstruction with synthetic grafts. A review of literature. International Orthopaedics. 2010 Apr 1;34(4):465-71. Google Scholar ; https://doi.org/10.1007/s00264-010-0963-2