MENISCAL ALLOGRAFT TRANSPLANTATION: AN OVERVIEW AND FUTURE DIRECTIONS

Bijay Pariyar[1], Bhim Sigdel[2], Niranjan Aryal[3], Sunil Pahari[4]

[1]*Orthopaedic Surgeon, Department of Orthopaedics and Trauma Surgery, Pokhara Academy of Health Sciences, Pokhara, Nepal.*

[2]*Orthopaedic Surgeon, Department of Orthopaedics and Trauma Surgery, Pokhara Academy of Health Sciences, Pokhara, Nepal.*

[3]*Orthopaedic Surgeon, Department of Orthopaedics and Trauma Surgery, Pokhara Academy of Health Sciences, Pokhara, Nepal.*

[4]*Orthopaedic Surgeon, Department of Orthopaedics and Trauma Surgery, Pokhara Academy of Health Sciences, Pokhara, Nepal.*

ABSTRACT:

The structure of the menisci allows the effective distribution of load across the knee joint. Even though our first priority goes to meniscus-preserving surgery, but many tears are irreparable, and many repairs are not successful. It is widely accepted that partial meniscectomy leads to early onset of osteoarthritis (OA). Meniscal allograft transplantation (MAT) was developed as a means of treating the symptoms of compartmental overload after meniscectomy and numerous case series have reported a significant improvement in knee function with reasonable rates of complication and survival, but randomized controlled trials have not been undertaken. Meniscal allograft transplantation has been performed for more than 30 years and numerous case series have consistently reported as protective of cartilage. The main goal of this review article is to provide an overview and current status of the role of MAT and also discussed the directions to advance the MAT in the future.

Keyword: *Meniscal allograft transplantation[1], meniscus replacement[2], meniscus repair[3], meniscectomized knee[4].*

INTRODUCTION:

The menisci are a wedge-shaped semilunar disc of fibrocartilaginous tissue, which is located between the tibia and the condyles of the femur in the medial and lateral compartments of the knee [1]. The ligaments which are attached to the tibia at both the anterior and the posterior horns by insertional ligaments, and to the deep medial collateral ligament, the transverse or intermeniscal ligament and two meniscofemoral ligaments [2]. Normally, menisci are composed of 75% of water and the remaining percentage composed of organic matters like collagen (mostly Type I, with smaller quantities of Types II, III, and V), proteoglycans and elastin [3]. When we go back to history, menisci were used to be considered the vestigial remnants of a muscle within the knee joint, but they have important biomechanical functions within the knee. Having functions as load sharers, shock absorbers, proprioception, joint

lubrication and nutrition of the articular cartilage, they are also functioning secondary stabilizers particularly in the absence of a functioning anterior cruciate ligament [4].

In orthopedic sports medicine, meniscal tears are one of the most common injuries with an incidence of 24 per 100,000 per year and show a bimodal distribution with a first peak in the young and athletic population, and the second peak in middle-aged patients with degenerative joint disease [5]. The most common cause of knee injuries is an injury during sports activity, which is often combined with anterior cruciate ligament (ACL) rupture [6]. Meniscus surgery is the most frequently performed procedure done by orthopedic surgeons (especially sports medicine surgeons) and have quickly advanced from an open procedure to arthroscopic surgery during the previous two decades [7,8]. Though meniscectomy has been promoted as the treatment of choice for many years, the fundamental principle of meniscus surgery is to preserve as much 'normal' meniscus as possible [9]. Therefore, the meniscal tears with a high probability of healing with surgical intervention are repaired (meniscus repair) but most tears are not repairable and partial to total meniscectomy is an alternative[10,11].

To preserve meniscal functions, Meniscal repairs and partial meniscectomies are attempted,but patient-specific factors such as age, concomitant injury, location and size of the tear, degree of injury, recurrent meniscal injury, and tear pattern frequently require subtotal or total meniscectomy, which was the recommended management of meniscal tears since the second half of the 19th century[12,13]. Thus, for central and unstable lesions in the white zone of the meniscus, meniscectomy was indicated to obtain a better short-term outcome[14], but the consequence of the partial or complete loss of the meniscus leads to early development of chondromalacia and osteoarthritis[15]. It has been advocated that the contact area between the tibia and femur is reduced by 50% in a meniscectomized knee[16], and represents a significant risk factor for definite radiological tibiofemoral osteoarthritis(OA) after 21 years with a relative risk of 14.0 (95% confidence intervals) [17].

Thus, to reduce the drawbacks of meniscectomy, to restore the functions of the meniscus, and to reduce pain in a meniscectomized knee, Meniscal allograft transplantation (MAT) has been introduced. The main objective of this review article is to provide an overview and current status of the role of MAT in the management of a case of total meniscectomy and also to improve the understanding of MAT with a recently published data. Additionally, directions to advance the MAT in the future are also discussed.

MENISCAL ALLOGRAFT TRANSPLANTATION:

Meniscal allograft transplants are not better than normal but maybe better than absent. In history, Meniscal replacement began to step forward in the 1980s as a response to the consequences of meniscectomy. In 1989, Milachowski and his team[18] reported a case series of meniscal transplantation in 30 sheep and 22 human patients, where the first human meniscal allograft transplant was performed by this group in May 1984 and concluded that meniscal allograft transplantation was a logical procedure and provide no adverse immunological reactions. The main objective of MAT was to prevent and sometimes even reverse the progressive joint degeneration in a meniscectomized knee. Kazi et al (2015) performed a 15- years follow-up study of eighty-six allograft of mean age 40 years and found that the graft survivorship is good, providing a mean of 12.5 years prior to knee arthroplasty in those requiring conversion with 71 % of allografts still in situ and functioning at a mean of 15 years post-surgery[19].

In 2014, McCormick et al,[20] underwent MAT of 200 patients with mean age of 34.3+/- 10.3 years, Eight of 172 patients (4.7%) went on to require revision MAT or total knee replacement. There was a 32% reoperation rate for MAT, with simple arthroscopic debridement being the most common surgical treatment (59%), and a 95% allograft survival rate at a mean of 5 years. The technique he used was Bridge-in-slot with exception of patients undergoing ACL reconstruction. In addition, Van Der Straeten C et.al. (2016) indicates that meniscal allograft transplantation (MAT) performs well in patients younger than 35with no-to-mild cartilage damage. These patients may benefit from MAT for the relief of symptoms, but patients and surgeons should be aware of the high number of surgical re-interventions[21].

The major indications for MAT are [22]:

- Total or subtotal knee meniscectomy with early arthritis - to delay the progression of degeneration
- Prophylactic transplantation - to avoid consequences of meniscectomy

- Loss of anterior cruciate ligament (ACL) - to provide additional stabilization and protection of the ACL
- Concomitant osteotomy- to improve the effect of the high tibial osteotomy and to delay recurrent deformity
- Failure of conservative treatment

In addition to the above indications, the patient must have pain in the compartment. This compartment-specific pain in the meniscectomized knee is termed as the "post-meniscectomy syndrome." Thus, the ideal patient for MAT is young patient, without any ligamentous instability, an appropriate axial alignment has intact cartilage surfaces, and has focal pain in the meniscus deficient compartment [23].

CONTRAINDICATIONS FOR MAT:

Patients with severe degenerative changes in the knee joint and BMI > 35 kg/m^2 are contraindicated for MAT. Instability, malalignment, open physes, effusion, and history of infection in the knee joint should be also included in the list of contraindications [22,24]. Patients with Noncorrectable grade IV chondromalacia especially those with opposing cartilage surfaces, should not be considered candidates for MAT [25].In contrast, kempshall et.al.[26] concluded that patients with advanced chondral damage should not be excluded from MAT.

PRE-OPERATIVE EVALUATION:

For meniscal transplantation, the initial assessment of suitable patient starts from a careful history and thorough physical examination because proper patient selection is the key to success with this procedure. Physical examination should include the evaluation of lower extremity alignment, ligament status, and gait, along with the presence of joint line tenderness, positive McMurray's sign, and effusion should also be determined [27].All the above-mentioned contraindications and indications for MAT should be strictly followed to achieve the better outcome. Rodeo et.al [28] found that standing radiographs including flexion views of the knee joint to examine the flexion weight-bearing zone of the femoral condyle, and standing hip-to-ankle views for assessment of the mechanical axis are required prior to surgery. They also concluded that magnetic resonance imaging(MRI) is possibly the most sensitive tool for the assessment of subchondral bone remodeling, subchondral marrow edema, as well as early softening and fibrillation of hyaline cartilage [28].

GRAFT PROCESSING AND GRAFT SIZING :

Fresh tissue is an ideal meniscal transplant, but due to logistical difficulties and cost issues, fresh frozen and non-irradiated implants give good results. The aggressive preservation and sterilization techniques can reduce the material properties of the meniscus transplant and the risk of disease transmission cannot be omitted completely. Although autogenic tissues are free from infection, always available and inexpensive, but the material properties of autogenic tissues are substandard in comparison to the allograft [29]. Meniscal allografts may be fresh, cryopreserved, fresh frozen, or lyophilized where fresh and cryopreserved allografts contain viable cells at the time of transplantation, while fresh-frozen and lyophilized tissues are acellular [28]. Shukur Ahmad et. al.(2017) performed hypothesis that cryopreserved meniscal allograft would maintain the original biomechanical properties compare to fresh frozen allografts and found that cryopreserved menisci showed a higher elastic modulus and higher ultimate tensile strength than fresh frozen. They achieve a significant difference between the two methods of preservations and recommend the use of cryopreserved meniscus as it retains the meniscus biomechanical properties [30].

Careful attention should be paid to obtaining a properly sized graft because a successful meniscal allograft transplantation procedure starts with appropriate size matching. Oversized meniscal allografts increased the forces across the articular cartilage, whereas undersized allografts resulted in normal forces across the articular cartilage, described by Deinst and his coworkers [31]. The most reliable methods of predicting the meniscal size for transplantation is described by Kaleka et.al. [32]. According to this study, considering MRI as the gold standard,

Yoon method [33] can be used to assess length for the lateral meniscus and the Pollard method [34] is considered a satisfactory alternative for the medial meniscus. Anthropometric data are an alternative for the width of the graft.

SURGICAL TECHNIQUES:

In the past 2 decades, several techniques have been described for MAT, which has included open and arthroscopically assisted techniques and these techniques are divided into two major groups: fixation with bone plugs or blocks and soft tissue fixation without bone plugs. The International Meniscus Reconstruction Experts Forum (IMREF) believes that there is no superiority of one surgical technique over another technique (bone fixation vs soft tissue). The practice within the IMREF group observed that 74% of surgeons like better to use bone fixation compared with 26% preferring soft tissue. Of those surgeons using bone fixation, the first choice goes for a slot or bone bridge technique on the lateral side and bone plugs for the medial side [35].The most commonly performed bone fixation methods are double bone plugs and bone bridge techniques (dovetail, trough, and keyhole). Moreover, MAT without bone plugs has shown good and excellent results in terms of pain relief and clinical and functional outcomes [36,37], though the degree of extrusion is higher than the bony fixation[38].

In 2013, Roumazeille et al. [39] performed minimally invasive arthroscopy with fresh-frozen allograft without bone plugs in 22 patients of mean age 37 ± 7.5 years, but the 6-months follow-up were 14 patients, out of which the results show 8/14 (57.1 %) had total graft healing, 2/14 (14.3 %) partial healing and 4/14 (28.6 %) no healing. However, at final follow-up, all functional scores had significantly improved and the average pre- and post-operative joint space thickness was similar. In 2016, Zaffagnini et.al [40] stated that Arthroscopic MAT without bone plugs improved function of knee and pain reduction, allowing return to sports in 74% of patients and return to the pre-injury activity level in 49% of patients at midterm follow-up and also conclude that only age at surgery seemed to affect outcomes. Lee et.al.[41] performed arthroscopic medial meniscal transplantation with modified bone plug technique where preparation of anterior bone plug with a long cylindrical shape and the posterior bone plug with a flat bone shell containing a cancellous portion was done which helps to facilitates easy fixation of the posterior bone plug as well as bone-to-bone healing. The bone plug technique also performed by Woodmass et.al [42] but in lateral meniscal transplantation and described the advantages of osseous integration and graft stability through a minimally invasive bone plug technique. The key-hole technique for MAT described by Lee et.al [43] is an effective technique in which an allograft with a bone bridge fixed to accommodate the key-hole –shaped slot which is properly secured with the slot. This technique helps to restore relatively normal anatomy of the meniscus and could be a curative procedure to delay articular cartilage degeneration.

In 2017, Monllau et.al [44] performed a simple, reproducible, and implant-free technique to perform a lateral capsular fixation (capsulodesis) at the time of lateral MAT in an effort to reduce or prevent graft extrusion. Recently, zhang et.al [45] designed two sets of surgical implements: first set to produce bone plugs of appropriate sizes in the anterior and posterior horns of the allograft meniscus i.e. bone plug implements and a second set to create bone tunnels in the receptor tibial plateau to hold the bone plugs i.e. bone tunnel implements. This study demonstrated that an all-arthroscopic approach to MAT was possible and the specifically designed surgical instruments for consistent preparation of grafts and recipient tissues contribute to a standardized approach to MAT. Overall, it is currently acknowledged that bone attachment of the anterior and posterior horns of the meniscus is the gold standard for MAT [46]. However, the trial of partial replacement of the meniscus by means of meniscal scaffolds mainly collagen or polyethane-based is going on and Tissue Engineering and Regenerative Medicine (TERM),which aim to develop new implants, biomaterials and biological enhancements of surgical approaches like cells, growth factors, proteins, nanotechnology, hydrogels,etc are the other advanced approaches which are under clinical trials and development [61].

REHABILITATION:

Rehabilitation after joint surgery plays an important role to evaluate the outcome of that surgery. The principle behind rehabilitation after MAT is to facilitate the return of knee function while respecting the healing process of the allograft tissue. Zaffagnini et.al [40] in 2016 applied postoperative rehabilitation by immobilization for 2 weeks and

then toe-touch weight bearing but restricted the range of motion (ROM). Then followed by isometric exercises, closed chain strengthening, and ROM from 0 to 90° during 3-4 weeks. Full weight-bearing started at week 6 postoperatively and patients were allowed to fully flex the knee joint. The sport-specific exercises and running were started after 3 months. The low-demand recreational activities like ballet, tennis, skiing, baseball, and boxing were not allowed until the 4th month and before 8 months postoperatively, patients were advised not to involved in competitive sports activities such as soccer, basketball, rugby, and volleyball. Likewise, Kempshall et.al. [26] applied the first 6 weeks of rehabilitation as limited weight bearing to diminish the traction forces on the meniscal root anchor points and followed by early ROM from 0 to 90° and active static quadriceps exercises are commenced with avoidance of open chain quadriceps exercises during this early period. After 6 weeks postoperatively, weight bearing, strengthening, and proprioceptive rehabilitation are steps forward. A functional and sports-specific rehabilitation programme starts from 6 months with a return to normal activities from approximately 9_months.

Marcacci et al (2014) [47] reported a series of 12 professional soccer players who underwent MAT, in which 92% returned to playing soccer professionally. At 36-months follow-up, 9 players (75%) were still playing professionally and 2 were playing semi-professionally. The mean time for returning to competition was 10.5 months and all the clinical scores improved. These facts may allow us to widen the indications to competitive sportsmen, though the high-level clinical data to assess the long-term results of MAT in athletes are still not available. Noyes et.al. estimated the probability of survival for all transplants was 85% at 2 years, 77% at 5 years, 69% at 7 years, 45% at 10 years, and 19% at 15 years [48]. According to International Meniscus Reconstruction Experts Forum (IMREF) 2015, a rehabilitation program and return-to-sport prescriptions are designed to consist of 4 stages [35]:

- Stage 1: Early restorative phase (0-8 weeks)
- Stage 2: Strength and conditioning phase (2-6 months)
- Stage 3: Functional rehabilitation progression phase (6-9 months)
- Stage 4: Sport-specific training and return to sport (>_9 months)

FOLLOW-UP EVALUATION/OUTCOME AFTER MAT:

In most studies, the outcomes of MAT have been evaluated using clinical parameters. In addition to detailed physical examination, post-operative evaluation is performed by use of clinical parameters such as the Lysholm score and Tegner activity scale [49], and international knee documentation committee (IKDC) scores [50], as well as Short Form 12 (SF-12), visual analog scale and modified pain scores [51,52]. Although the proven benefits of the procedure are pain relief and functional improvement, these clinical assessments do not accurately reflect the status of meniscal transplants. It is more sensible to carefully assess the graft condition itself and for this diagnostic arthroscopy is the most accurate objective evaluation method, but is an invasive modality. Thus, Radiographic evaluation and MRI scans are more commonly used as a relatively reliable and noninvasive evaluation method [52].

The knee injury and osteoarthritis outcome score (KOOS) is a region-specific score that is widely accepted and presents a measure of the general status of the knee. This is self-administered and evaluates five outcomes: pain, symptoms, activities of daily living, sport and recreation function, and knee-related quality of life. KOOS is particularly important as MAT patients often have significant concomitant knee pathology and has been shown to be responsive to change in patients with knee Osteoarthritis [53]. The western ontario meniscal evaluation tool (WOMET) [54] is a disease-specific score and validates a health-related quality of life (HRQOL) index for patients with meniscal pathology. The other evaluation tool is the marx activity rating scale [55], which is a 4-item activity rating scale. In this tool, patients are asked to rate how often they were able to perform each activity like running, cutting, decelerating, and pivoting in their most healthy and active state. The EQ-5D tool developed by the EuroQol Group [56] is a quality of life and utility tool that is easy to use and becoming more accepted internationally.

FUTURE DIRECTIONS:

Meniscal allograft transplantation appears as a useful alternative for selected patients with a stable knee and appropriate alignment where some long-term studies prove that cartilage protection is achievable [57]. MAT is an

effective biologic reconstruction method for a meniscectomized knee that reduces symptoms in the affected compartment. Although complications including a tear of the allograft, synovitis, effusion, or infection have been reported, when considering only isolated MAT, the acceptable complication rate is 3.6 % [58]. Therefore, the orthopedic surgeons should keep in mind that transplanted menisci could not restore perfectly the normal meniscal function but just improve functions with a possible chondroprotective effect in the meniscectomized knee [59]. Patients should be clearly advised that the procedure is not curative in the long term, and additional surgery will likely be required. Recently, Nordberg et.al. [60] provides a new method for enhanced cellular infiltration in meniscal allografts where human adipose-derived stem cells(hASC) can be easily isolated in large quantities for autologous use and could be an ideal cell source to repopulate an allograft scaffold before transplantation into the patient. This study enhanced successful tissue engineering utilizing hASC, which could improve long-term efficacy of MAT procedures by maintaining the meniscus in vivo. Therefore, High-quality prospective comparative trials and randomized control trials with larger sample sizes are required to further evaluation of the most appropriate technique and selection of the graft. However, more data are necessary to verify the pre-operative evaluation, complication, survivorship, reoperation, and failure rates of MAT. The logistics difficulties and cost issues should be direct properly, and the rehabilitation time after MAT must be idealized to secure the better outcome.

CONCLUSIONS:

The anatomy and microstructure of the meniscus allow the effective distribution of load across the knee joint. Our overview of treatment for meniscectomized knee shows some promising step forward in the understanding of the important role of the meniscus that has led to a move toward meniscal transplantation. The goal of transplantation is to prevent and possibly even reverse the progressive joint degeneration that predictably follows meniscectomy. Careful patient selection and referral to subspecialty-trained, higher-volume surgeons should be considered to optimize clinical outcomes. Therefore, MAT seems to be a reasonable treatment option in correctly selected patients.

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REFERENCES:

[1]. Fox AJS, Bedi A, Rodeo SA: The Basic Science of Human Knee Menisci Sports Health. Sports Health: 340-51, 2012.

[2]. Masouros SD, McDermott ID, Amis AA, Bull AM: Biomechanics of the meniscusmeniscal ligament construct of the knee. Knee Surg Sports Traumatol Arthrosc 16: 1121–1132, 2008.

[3]. McDevitt CA, Webber RJ: The ultrastructure and biochemistry of meniscal cartilage. Clin Orthop Relat Res 252: 8–18, 1990.

[4]. McDermott ID, Amis AA: The consequences of meniscectomy. J Bone Joint Surg Br. 88(12): 154956, 2006.

[5]. Clayton RA, Court-Brown CM: The epidemiology of musculoskeletal tendinous and ligamentous injuries. Injury 39(12): 1338–1344, 2008.

[6]. Salata MJ, Gibbs AE, Sekiya JK: A systematic review of clinical outcomes in patients undergoing meniscectomy. Am J Sports Med 38: 1907–1916, 2010.

[7]. Baker BE, Peckham AC, Pupparo F et al: Review of meniscal injury and associated sports. Am J Sports Med 13: 1–4, 1985.

[8]. Shybut T, Strauss EJ: Surgical management of meniscal tears. Bull NYU Hosp Joint Dis 69: 56–62, 2011.

[9]. Hede A, Larsen E, Sandberg H: The long-term outcome of open total and partial meniscectomy related to the quantity and site of the meniscus removed. Int Orthop 16(2): 122-5, 1992.

[10]. Laible C, Stein DA, Kiridly DN. Meniscal repair: J Am Acad Orthop Surg 21(4): 204–213, 2013.

[11]. Mezhov V, Andrew J. Teichtahl, Rupert Strasser, Anita E Wluka, and Flavia M Cicuttini: Meniscus pathology - the evidence for treatment. Arthritis Res Ther 16(2): 206, 2014.

[12].Englund M, Roos EM, Roos HP et al: Patient-relevant outcomes fourteen years after meniscectomy: influence of type of meniscal tear and size of resection. Rheumatology (Oxford) 40:631–9, 2001.

[13].Allen PR, Denham RA, Swan AV: Late degenerative changes after meniscectomy. Factors affecting the knee after operation. J Bone Joint Surg Br. 66: 666-671, 1984.

[14]. Biedert RM: Treatment of intrasubstance meniscal lesions: a randomized prospective study of four different methods. Knee Surg Sports Traumatol Arthrosc. 8: 104–108, 2000.

[15]. Rao AJ, Erickson BJ, Cvetanovich GL, Yanke AB, Bach BR Jr, Cole BJ: The Meniscus-Deficient Knee: Biomechanics, Evaluation, and Treatment Options. Orthop J Sports Med.3(10): 2325967115611386, 2015.

[16].Ahmed AM, Burke DL: In-vitro measurement of static pressure distribution in synovial joints—Part I: Tibial surface of the knee. J Biomech Eng. 105(3): 216–25, 1983.

[17].Roos H, Lauren M, Adalberth T, Roos EM, Jonsson K, Lohmander LS: Knee osteoarthritis after meniscectomy: prevalence of radiographic changes after twenty-one years, compared with matched controls. Arthritis Rheum. 41(4): 687–93, 1998.

[18]. Milachowski KA, Weismeier K, Wirth CJ: Homologous meniscus transplantation: Experimental and clinical results. Int Orthop 13: 1–11, 1989.

[19].Kazi HA, Abdel-Rahman W, Brady PA, Cameron JC: Meniscal allograft with or without osteotomy: a 15-year follow-up study. Knee Surg Sports Traumatol Arthrosc. 23: 303-9, 2015.

[20]. McCormick F, Harris JD, Abrams GD, Hussey KE, Wilson H, Frank R, Gupta AK, Bach BR Jr, Cole BJ: Survival and reoperation rates after meniscal allograft transplantation: analysis of failures for 172 consecutive transplants at a minimum 2-year follow-up. Am J Sports Med. 42: 892-7, 2014.

[21]. Van Der Straeten C, Byttebier P, Eeckhoudt A, Victor J: Meniscal allograft transplantation does not prevent or delay progression of knee osteoarthritis. PLoS One. 11(5): e0156183, 2016.

[22]. Peters G, Wirth CJ: The current state of meniscal allograft transplantation and replacement. Knee.10(1): 19-31, 2003.

[23].Sekiya JK, Ellingson CI: Meniscal allograft transplantation. J Am Acad Orthop Surg. 14(3): 164-74, 2006.

[24]. Chahla J, Olivetto J, Dean CS, Serra Cruz R, LaPrade RF: Lateral Meniscal Allograft Transplantation: The Bone Trough Technique. Arthrosc Tech.5(2): e371-e377, 2016.

[25]. LaPrade RF, Willlls NJ, Spiridonov SI, Perkinson S: A prospective outcomes study of meniscal allograft transplantation. Am J Sports Med 38: 1804-1812, 2010.

[26]. Kempshall PJ, Parkinson B, Thomas M, Robb C, Standell H, Getgood A, Spalding T: Outcome of meniscal allograft transplantation related to articular cartilage status: advanced chondral damage should not be a contraindication. Knee Surg Sports Traumatol Arthrosc. 23(1): 280-9, 2015.

[27]. Jarit GJ, Bosco JA 3rd: Meniscal repair and reconstruction. Bull NYU Hosp Jt Dis. 68(2): 84-90, 2010.

[28].Rodeo SA: Meniscal allografts--where do we stand? Am J Sports Med. 29(2): 246-61, 2001.

[29]. Messner K, Kohn D, Verdonk R: Future research in meniscal replacement. Scand J Med Sci Sports 9: 181–183, 1999.

[30]. Ahmad S, Singh VA, Hussein SI: Cryopreservation versus fresh frozen meniscal allograft: A biomechanical comparative analysis. J Orthop Surg (Hong Kong). 25(3): 2309499017727946, 2017.

[31]. Dienst M, Greis PE, Ellis BJ, et al: Effect of lateral meniscal allograft sizing on contact mechanics of the lateral tibial plateau: an experimental study in human cadaveric knee joints. Am J Sports Med.35: 34-42, 2007.

[32]. Kaleka CC, Netto AS, Silva JC, Toma MK, de Paula Leite Cury R, Severino NR, Santili C: Which Are the Most Reliable Methods of Predicting the Meniscal Size for Transplantation? Am J Sports Med. 44(11): 2876-2883, 2016.

[33].Yoon JR, Kim TS, Lim HC, Lim HT, Yang JH: Is radiographic measurement of bony landmarks reliable for lateral meniscal sizing? Am J Sports Med. 39(3): 582-589, 2011.

[34]. Pollard ME, Kang Q, Berg EE: Radiographic sizing for meniscal transplantation. Arthroscopy.11: 684-687, 1995.

[35]. Getgood A, LaPrade RF, Verdonk P, Gersoff W, Cole B, Spalding T; IMREF Group: International Meniscus Reconstruction Experts Forum (IMREF) 2015 Consensus Statement on the Practice of Meniscal Allograft Transplantation. Am J Sports Med. pii: 0363546516660064. [Epub ahead of print], 2016.

[36]. Wipfler B, Donner S, Zechmann CM, Springer J, Siebold R, Paessler HH: Anterior cruciate ligament reconstruction using patellar tendon versus hamstring tendon: a prospective comparative study with 9-year follow-up. Arthroscopy. 27(5): 653-65, 2011.

[37]. Alentorn-Geli E, Seijas R, García M, et al: Arthroscopic meniscal allograft transplantation without bone plugs. Knee Surg Sports Traumatol Arthrosc 19: 174-182, 2011.

[38]. Abat F, Gelber PE, Erquicia JI, Pelfort X, Gonzalez-Lucena G, Monllau JC: Suture-only fixation technique leads to a higher degree of extrusion than bony fixation in meniscal allograft transplantation Am J Sports Med. 40(7): 1591-6, 2012.

[39]. Roumazeille T, Klouche S, Rousselin B, Bongiorno V, Graveleau N, Billot N, Hardy P: Arthroscopic meniscal allograft transplantation with two tibia tunnels without bone plugs: evaluation of healing on MR arthrography and functional outcomes. Knee Surg Sports Traumatol Arthrosc. 23: 264-9, 2015.

[40]. Zaffagnini S, Grassi A, Marcheggiani Muccioli GM, et al: Is sport activity possible after arthroscopic meniscal allograft transplantation? Midterm results in active patients. Am J Sports Med. 44(3): 625-632, 2016.

[41]. Lee DW, Park JH, Chung KS, Ha JK, Kim JG: Arthroscopic Medial Meniscal Allograft Transplantation with Modified Bone Plug Technique. Arthrosc Tech. 6(4): e1437-e1442, 2017.

[42]. Woodmass JM, Johnson NR, Levy BA, Stuart MJ, Krych AJ: Lateral Meniscus Allograft Transplantation: The Bone Plug Technique. Arthrosc Tech. 6(4): e1215-e1220, 2017.

[43]. Lee DW, Park JH, Chung KS, Ha JK, Kim JG: Arthroscopic Lateral Meniscal Allograft Transplantation With the Key-Hole Technique. Arthrosc Tech. 6(5): e1815-e1820, 2017.

[44].Monllau JC, Ibañez M, Masferrer-Pino A, Gelber PE, Erquicia JI, Pelfort X: Lateral Capsular Fixation: An Implant-Free Technique to Prevent Meniscal Allograft Extrusion. Arthrosc Tech. 6(2): e269-e274, 2017.

[45].Zhang YD, Hou SX, Zhong HB, Zhang YC, Luo DZ: Meniscal allograft transplantation using a novel all-arthroscopic technique with specifically designed instrumentation. Exp Ther Med. 15(3): 3020-3027, 2018.

[46]. Vaquero J and Forriol F: Meniscus tear surgery and meniscus replacement: Muscles Ligaments Tendons J 6: 71-89, 2016.

[47].Marcacci M, Marcheggiani Muccioli GM, Grassi A, et al: Arthroscopic meniscus allograft transplantation in male professional soccer players: a 36-month follow-up study. Am J Sports Med. 42(2): 382-388, 2014.

[48]. Noyes FR, Barber-Westin SD: Long-term Survivorship and Function of Meniscus Transplantation. Am J Sports Med. 44(9): 2330-8, 2016.

[49].Tegner Y, Lysholm J: Rating systems in the evaluation of knee ligament injuries. Clin Orthop Relat Res.198: 43–49, 1985.

[50].Anderson AF, Irrgang JJ, Kocher MS, Mann BJ, Harrast JJ: The international knee documentation committee subjective knee evaluation form: normative data. Am J Sports Med. 34: 128–135, 2006.

[51]. Hommen JP, Applegate GR, Del Pizzo W: Meniscus allograft transplantation: ten-year results of cryopreserved allografts. Arthroscopy. 23(4): 388-93, 2007.

[52]. Lee BS, Kim JM, Sohn DW, Bin SI: Review of Meniscal Allograft Transplantation Focusing on Long-term Results and Evaluation Methods. Knee Surg Relat Res. 25(1): 1-6, 2013.

[53]. Roos EM, Roos HP, Lohmander LS, Ekdahl C, Beynnon BD: Knee Injury and Osteoarthritis Outcome Score (KOOS): development of a self-administered outcome measure. J Orthop Sports Phys Ther. 28(2): 88-96, 1998.

[54]. Kirkley A, Griffin S, Whelan D: The development and validation of a quality of life-measurement tool for patients with meniscal pathology: the Western Ontario Meniscal Evaluation Tool (WOMET). Clin J Sport Med. 17(5): 349-356, 2007.

[55]. Marx RG, Stump TJ, Jones EC, Wickiewicz TL, Warren RF: Development and evaluation of an activity rating scale for disorders of the knee. Am J Sports Med. 29(2): 213-218, 2001.

[56].Rabin R, de Charro F: EQ-5D: a measure of health status from the EuroQol Group. Ann Med. 33(5): 337-343, 2001.

[57]. Peters G, Wirth CJ: The current state of meniscal allograft transplantation and replacement. Knee. 10(1): 19-31, 2003.

[58]. Rosso F, Bisicchia S, Bonasia DE, Amendola A: Meniscal allograft transplantation: a systematic review. Am J Sports Med. 43(4): 998-1007, 2015.

[59]. Kim JG, Lee YS, Bae TS, Ha JK, Lee DH, Kim YJ, Ra HJ: Tibiofemoral contact mechanics following posterior root of medial meniscus tear, repair, meniscectomy, and allograft transplantation. Knee Surg Sports Traumatol Arthrosc. 21(9): 2121-5, 2013.

[60]. Nordberg RC, Charoenpanich A, Vaughn CE, Griffith EH, Fisher MB, Cole JH, Spang JT, Loboa EG: Enhanced cellular infiltration of human adipose-derived stem cells in allograft menisci using a needle-punch method. J Orthop Surg Res. 11(1): 132, 2016.

[61]. H Pereira, IF Cengiz, S Gomes, JE Mendes, PL Ripoll, JC Monllau, RL Reis, JM Oliveira, EFORT Open Rev .;4(6):279-295. 2019.