

## Original Article

# Comparison of the bone plug and bone bridge technique for lateral meniscus allograft transplantation

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**Abstract:** Background: Studies have reported that for the meniscal allograft transplantation (MAT), the Bone Bridge method (Bone Bridge) and the Bone Plug method (Bone Plug) show better clinical improvements than simple soft tissue suture after meniscectomy in the knee. However, there are rare studies comparing the long-term postoperative outcomes between the Bone Plug and the Bone Bridge which are used for lateral MAT. Objective: This study aims to compare the long-term clinical outcomes of Bone Plug and Bone Bridge in lateral MAT. Methods: From January 2010 to July 2013, 30 postoperative lateral MAT patients were enrolled to check the follow-up outcomes. Among the 30 cases, 18 cases were Bone Plug; 12 cases were Bone Bridge. We use three methods to compare the long-term clinical outcomes, which are visual analog scale (VAS), Lysholm knee evaluation scale and Tegner activity scale. All patients underwent MRI examination in the final follow-up to observe the morphology and signal changes in the meniscus after MAT. Results: All of the 30 patients were followed up for  $24.3 \pm 1.8$  months (range, 21-27 months) after MAT. After 2 years, no patient was found to have meniscal mechanical symptoms, effusion, lateral joint line tenderness or a positive McMurray test. Their results in VAS, Lysholm knee evaluation scale and Tegner activity scale significantly improved after MAT for 2 years ( $P < 0.05$ ). MRI showed that the allograft menisci have satisfactory condition within 2 year post-operation period. There was no significant difference in the postoperative long-term outcomes between Bone Plug and Bone Bridge ( $P > 0.05$ ) in lateral MAT. Conclusion: Clinical results of both MAT methods were satisfactory. But there was no significant difference in the postoperative long-term outcome between Bone Plug and Bone Bridge in lateral MAT. They also have an advantage for patients who undergo lateral meniscus allograft transplantation.

**Keywords:** Lateral meniscal transplantation, allograft, arthroscopic surgery

## Introduction

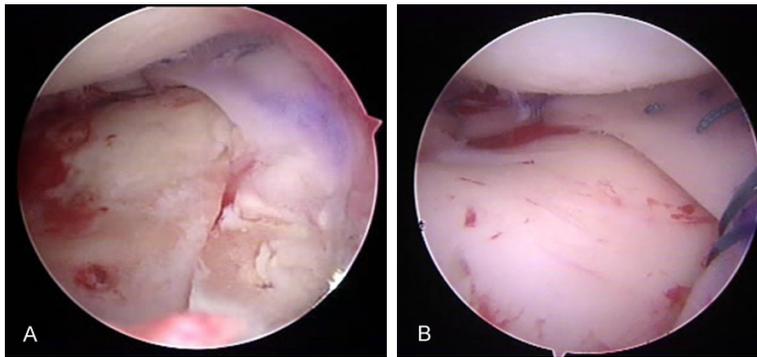
The meniscus is one of the most important structures for maintaining the knee function which is a pair of coarse cartilage bundles circumferentially arranged to disperse compressive load and radially resist shear [1]. Meanwhile, it significantly improves morphological match ability between tibia and femur [2]. Meniscal deficiency can accelerate cartilage degeneration and increase the occurrence of osteoarthritis. Although meniscectomy demonstrates good short-term functional recovery, it accelerates the degeneration of articular cartilage. It has been recognized that meniscus cannot be abandoned [3]. MAT provides good

solutions for patients who are clinically impractical to retain their meniscus [4]. Currently, two methods are mainly used for meniscal transplantation: Bone Plug and Bone Bridge. However, there are only limited researches concerning the long-term effects of these two methods [5]. Recognizing, Bone Plug is limited to the medial meniscus transplantation [6, 7], whilst Bone Bridge is used for lateral transplantation. The purpose of this study was to compare the long-term prognosis of the two kinds of methods in the context of lateral MAT and whilst provide evidence to support the further clinical development of MAT. We hypothesized that both Bone Plug and Bone Bridge can successfully use in lateral MAT.

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**Figure 1.** A. Human meniscal allograft before trimming. B. Human meniscal allograft with a bone bridge connecting the anterior and posterior horns. C. Human meniscal allograft with a cylindrical bone plug on the attachment site of the anterior and posterior horn meniscus.



**Figure 2.** A. Human meniscal allograft fixated with bone bridge under arthroscopy; B. Human meniscal allograft fixated with bone plug under arthroscopy.

### Methods

#### *Participant & allograft material*

This was a hospital-based retrospective study. A total of 30 postoperative MAT patients (19 male, 11 female) were enrolled to observe the long-term follow-up outcomes from January 2010 to July 2013. All of the 30 patients had undergone lateral MAT in the knee through two different MAT methods. Before the MAT surgery, the include criteria for MAT was a previous subtotal or total meniscectomy followed by knee pain, joint swelling and joint space tenderness. 9 out of 30 cases had joint locking symptoms. 28 out of 30 cases had positive McMurray tests. Meanwhile, all patients' preoperative MRI examination showed that the meniscus signal was Grade-3. Meniscal injuries on MRI were scored according to a grading system described by Lotysch [8] and Crues [9] Grade-3 signal intensity on MRI was defined as abnormal signals in meniscus extending to the articular surface. A single abnormal

image was considered sufficient for diagnosing a meniscus as torn on MRI. Grade-1 and 2 signal changes in meniscus not reaching the articular surface were not considered tears. The exclude criteria for MAT were grade III or higher generalized degenerative arthritis, uncorrected instability, axial lower extremity malalignment, skeletal immaturity, and age over 60 years. Each subject had signed the informed consent before participating in our study.

This study was approved by the ethics committee of The First Affiliated Hospital of Shenzhen University and was conducted in conformity with the guidelines outlined in the Declaration of Helsinki statement.

Human meniscus allograft materials for transplantation were provided by the Beijing winkonHengye Biological Technology Co., Ltd.; the grafts were preserved through fresh-frozen method.

#### *MAT methods*

All transplantations were performed by 1 senior orthopedic surgeon (WL) at the First Affiliated Hospital of Shenzhen University. The arthroscopic evaluation was performed to determine the status of the meniscus and reshape them. During the reshape procedure, the remaining host meniscus was resected arthroscopically, leaving a peripheral rim of about 1 mm to leave a vascular source to aid in graft healing. And the capsule was retained after meniscectomy.

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**Table 1.** The comparison of VAS, lysholm, and tegner scores before and 2 years after MAT follow-up (x±s)

Period	Bone bridge		Bong plug	
	Preoperatively	24.2 months after MAT	Preoperatively	24.2 months after MAT
VAS scores	7.08±0.67	2.92±0.67**	6.94±0.73	2.89±0.68**
Lysholm knee score	64.58±4.27	84.08±5.70**	65.28±5.27	84.22±4.52**
Tegner activity level	1.75±0.45	4±0.74**	1.67±0.59	3.94±0.73**

P<0.05.

**Table 2.** The comparison of VAS, lysholm, and tegner scores between bone bridge and bone plug

12.5 months after MAT	MAT method		P
	Bone bridge	Bong plug	
VAS scores	2.92±0.67	2.89±0.68	0.91
Lysholm knee score	84.08±5.70	84.22±4.52	0.48
Tegner activity level	4±0.74	3.94±0.73	0.83

P>0.05

Magnification-controlled preoperative plain radiographs were used to select the size-matched graft according to the methods described by Pollard [10]. The size of donor meniscus (**Figure 1A**) should be 10% bigger than that of the receptor. We should select the same sex, ipsilateral and younger donor meniscus as far as possible.

We used Bone Bridge to fix the meniscus implantation. The menisci were transplanted with a bone bridge connecting the anterior and posterior horns by the keyhole technique [7] (**Figure 1B**). For the Bone Bridge of the lateral meniscus, a keyhole tibial slot was made just under the lateral tibial eminence. The keyhole is 30 mm in length and 7 mm in width on the top and 8 mm in width on the bottom made by osteotome. The meniscal allograft was introduced through an anterior miniarthrotomy. This would make the bone bridge insert into the keyhole. After the confirmation of the optimal allograft position, a traditional insideout meniscal repair was performed using No. 2-0 nonabsorbable sutures placed 3 to 5 mm apart (**Figure 2A**).

The other 18 cases used Bone Plug to fix the meniscus implantation in 30 patients. First, we trimmed the allogenic meniscus allograft (**Figure 1C**) in the surgical workbench. 2 bone plugs were prepared at the anterior and posterior horns of the graft. The bone plug was created using a quarter-inch osteotome and a mal-

let to create a cylindrical bone plug with the diameter of 7 mm centered at the attachment site of the anterior and posterior horn meniscus. We used the ACL guide to create two bone tunnels from the point that medial to the tibial tuberosity to the insertions of anterior and posterior horn meniscus. We passed sutures in the bone plugs down through the bone tunnels to the tunnel exit medial to the tibial tuberosity and tensioned the sutures. The bone plugs were reduced back to their respective insertions using the bone plug sutures. And then the meniscus was repaired back to the capsule using 2-0 Ethibond sutures placed in a vertical mattress configuration spaced into the anterior horn, body, and posterior horn of the meniscus (**Figure 2B**).

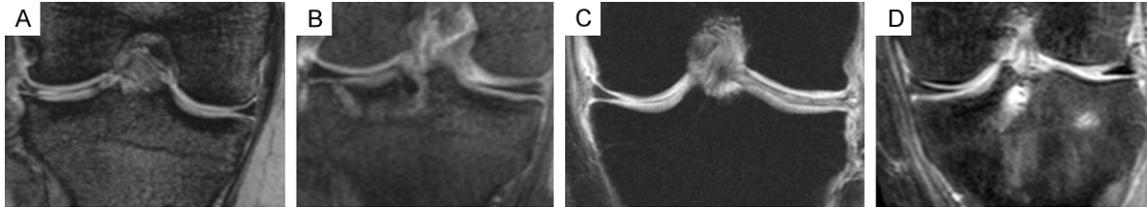
### Rehabilitation exercise

After surgery, the patients started to do quadriceps sets, straight-leg raises immediately. During 1 or 2 days after surgery, continuous passive motion exercises were practiced. And then, the goal of the passive motion exercises is to achieve 90° of flexion within 4 weeks, and 120° of flexion at 6 to 8 weeks. Patients could only toe-touch weight bearing during the first 2 weeks postoperatively and slowly increased to 50% of body weight in the fourth week and to full weight bearing in the sixth week. Rehabilitation sustained for about 3 months and focused on restoring the full range of motion and quadriceps strength. Patients should only participate only in low-impact sports and light labor. Contact sports or squatting activities were not allowed.

### Clinical outcome measures

The two procedures were compared in terms of the function using the Lysholm knee evaluation scale, Tegner activity scale, and VAS score [11]; modified Outerbridge cartilage gra-

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**Figure 3.** MRI observation of human meniscal allograft before and after the meniscus transplantation. A. Preoperative MRI showed serious meniscal defect; B. MRI showed meniscus was in good position after receiving MAT by Bone Bridge after 2 years; C. Preoperative MRI showed serious meniscal defect; D. MRI showed meniscus was in good position after receiving MAT by Bone Plug after 2 years.

des using MRI; All measurements were performed by 2 surgeons, who each have at least 5 years' experience in practice.

### Statistical analyses

The two procedures were compared in terms of the function using the Lysholm knee evaluation scale, Tegner activity scale, and VAS score. Data analysis was performed using SPSS 16.0 software (IBM Corp), and the data were reported as means and standard deviations. The statistical method was unpaired, two-tailed student's T-test. The significance level was set at  $P < 0.05$ .

### Results

All of the 30 patients were followed up for  $24.3 \pm 1.8$  months (range, 21-27 months) after MAT. Patients enrolled were  $32.5 \pm 7.6$  (range, 18-45) years of age. All data was gathered amongst the period. After 2 years, no patient complained of meniscal mechanical symptoms such as locking, catching, or giving way. No patient had a history of recurrent effusion. No patient had lateral joint line tenderness or a positive McMurray test. No patient had an obvious immune rejection. The range of motion was  $112.78 \pm 8.26$  after 24.3 months. At the final follow-up, the Lysholm knee score, the VAS scores and Tegner activity level significantly improved compared with the preoperative values ( $P < 0.05$ , **Table 1**). ( $x \pm s$ ) means mean  $\pm$  standard deviation. There were no significant differences between Bone Bridge and Bone Plug in the Lysholm knee score, the VAS scores and Tegner activity level after 2 years postoperatively ( $P > 0.05$ , **Table 2**). Therefore, Bone Bridge and Bone Plug used in lateral MAT was considered to have a good long-term clinical success rate.

The MRI shows tiny contrast enhancement inside the meniscus compares to the ipsilateral preoperative status. It showed that both Bone Bridge and Bone Plug got the good healing of meniscal allograft which the meniscus was at the normal status like the contralateral. The meniscal protrusion is defined in 2 anterior horns and 5 bodies of meniscal transplants. The MRI signal of the allograft was normal in 27/30 anterior horns and heterogenic in all body and posterior horns with degree II-III (**Figure 3A-D**). Meanwhile, the MRI reveals the grade 3 OA MRI grading which has a subchondral signal loss due to bone sclerosis.

### Discussion

There are two kinds of MAT methods in common use, Bone Plug and Bone Bridge. Generally considered, Bone Plug is limited to the medial meniscus transplantation, whilst Bone Bridge is used for lateral transplantation [6, 7]. The distance between the anterior horn and the posterior horn of the lateral meniscus is only 1 cm, and it is too short to creating two bone tunnels for inserting the plug. So surgeons always chose bone bridge method in this situation [7]. Because of the relatively huge trauma, we suggest that using the Bone Plug to fix the lateral meniscus allograft.

In Bone Plug, we need to insert the bone plugs which respectively sutured on anterior and posterior horns into the corresponding bone tunnel and fix with sutures. The meniscus surrounding is fixed with the joint capsule by sutures. This method is commonly used in the medial meniscus fixation [12, 13]. The regular bone plug is cylindrical with diameter 8 mm, but the bone plug of the posterior horn should be 1 mm smaller than standard size diameter in order to pass through the joint space and implant into a bone tunnel. We use bone plug measuring 7

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mm in anterior and posterior horns so as to successfully use Bone Plug in the lateral tibial plateau. During our long-term follow-up, Bone Plug in lateral MAT achieved good long-term clinical outcomes.

So far, regarding Bone Plug and Bone Bridge, Wang [14] propose that they have significant differences in improving the tibiofemoral joint contact area and stress. So they prefer to use Bone Bridge during MAT. Abat [13] propose that Bone Bridge can provide good primary stability, and this stability is the foundation for weight bearing in the future. Some researchers also suggest that Bone Bridge can achieve better long-term outcomes [15]. Nevertheless, our results show that there was no significant difference between Bone Plug and Bone Bridge in the long-term follow-up of the post-lateral MAT scores in the VAS, Lysholm knee evaluation scale and Tegner activity scale. Both methods can provide satisfactory outcomes for the patients.

Currently, MRI has been widely used in the diagnosis of the meniscus injury, but there are little MRI studies for prognosis of MAT. Vundelinckx proposed that MRI could be a good method for checking the state of meniscus after MAT [16]. However, some studies suggested that MRI could not reflect the clinical condition of MAT [17], Lee proposed that MRI is irrelevant to the clinical outcomes [18]. For example, meniscus protrusion is a common phenomenon after MAT [19, 20], but it does not adversely affect the clinical outcome after MAT [21]. Our MRI results suggested that some meniscal problems could not fully reflect the postoperative outcomes of MAT. During our follow-up, meniscus protrusion presented in 7 cases with signal changes, but it turns out that the patients had no corresponding symptoms as the MRI shows. Leef suggested that patients may have better recovery if MRI indicated that a) meniscus were in good position; b) there was no hyperintense signal inside the meniscus and; c) there was no effusion in the joint cavity [22, 23]. Therefore, we cannot predict the clinical outcomes of meniscal transplantation only based on the MRI results. However, MRI can provide assessments of allograft meniscal and articular overall situation in great value.

This study has several limitations. The number of patients included was small. We classified the patients into two groups and there were only nine patients in each group. And we believe that this data would be valuable for evaluating the long-term outcomes of the two different methods in the lateral MAT. Second, this was a retrospect study and do not have a control group and experimental group.

Clinical results of both MAT methods were satisfactory. But there was no significant difference in the postoperative long-term outcome between Bone Plug and Bone Bridge in lateral MAT. They also have an advantage for patients who undergo lateral meniscus allograft transplantation.

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### Disclosure of conflict of interest

None.

### Authors' contribution

DPW and WMZ conceived and designed the study. WL, WMZ and LQP performed the surgeries. LQP and JMC wrote the paper. LQP, JMC, YKO and KC reviewed and edited the manuscript. All authors read and approved the manuscript.

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