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Original Article

Comparison of the operation of arthroscopic tibial inlay and traditional tibial inlay for posterior cruciate ligament reconstruction

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Abstract: Objective: To perform dual-bundle reconstruction of posterior cruciate ligament using full arthroscopic tibial inlay technology with self-designed tibia tunnel drilling system and to compare the effect of arthroscopic tibial inlay versus traditional technique for posterior cruciate ligament reconstruction. Material and methods: 32 patients were randomly divided into experiment group (improved tibial inlay, n = 17) and control group (traditional tibial inlay, n = 15). Self-designed tibia tunnel drill system was used to produce intraoperative deep-limited bone tunnel. During follow-up, the location of the bone block and the healing situation were checked by knee X-ray and spiral CT scan. Blood loss, operation time and nerve vascular injuries were evaluated. Results: Mean intraoperative blood loss was 123.53 ± 74.05 ml in the improved tibial inlay group compared with 332 ± 114.26 ml in the traditional tibial inlay group (t = 6.12, P < 0.05). Mean operation time was 235.27 ± 58.88 min in the improved tibial inlay group compared with 346.37 ± 59.67 min in the traditional tibial inlay group (t = 5.19, P < 0.05). Posterior drawer test were negative in 15 cases, slight positive in 2 with improved tibial inlay technique compared with 14 negative cases and 2 positive cases of traditional tibial Inlay technique. The X-ray and spiral CT scan showed the location of the bone block were perfect and healed well with the patent who received improved tibial inlay technology after 12 weeks postoperatively. Conclusion: Accurate depth-limited bone tunnel can be produced by the tibia tunnel drill system with minor trauma, less bleeding and reducing of nerves or vessels and the recent clinical effects of PCL reconstruction were pretty good.

Keywords: Posterior cruciate ligament, inlays, arthroscopy

Introduction

PCL knee injuries caused by athletic injuries and traumas are increasing year by year. In the early days, Arthroscopy was one of the diagnostic tools because of its advantage of minimally invasive and the lack of other diagnostic methods. With the improvement of the clinical physical examination and the imaging diagnosis level, Arthroscopy is becoming a very important therapy method instead of being a checking method [1-3]. With the advances in arthroscopic techniques, PCL reconstruction is making a significant progress, therefore improved operation effect. The surgical indications of PCL injuries are as follows: 1) Suture fixation procedure should be performed as soon as possible under the circumstance of tibial or femoral avulsion or avulsion fracture. 2) Surgical reconstruction or repairmen of ligament is performed for III degree PCL injuries or combined knee injuries. 3) PCL reconstruction is performed in case of knee instability caused by Old PCL injuries [4-6]. The follow-up study demonstrates that the clinical result of arthroscopic PCL reconstruction is not as satisfactory as that of anterior cruciate ligament (ACL) reconstruction. The former may cause postoperative knee laxity. PCL reconstruction can improve the knee stability to some extent, however if it can slow down the degeneration of knee cartilage, the research still remains at the level of laboratory. PCL reconstruction still remains controversial currently [7-10]. Arthroscopic posterior cruciate ligament reconstruction is effective for PCL injuries and is accepted widely in sports medicine. The focus is “transtibial” or “tibial Inlay”. The reconstruction technique by tibial tunnel

Figure 1. Sketch diagram of cutting quadriceps tendon and the patella bone trimmed.

has always dominated, however its clinical effect is not better than that of ACL. Biomechanical and clinical study results confirmed that "killer turn" caused by the acute bending angle at the back of tibial tunnel was probably the main reason for the poor efficacy of PCL reconstruction [11, 12]. "Killer turn" results in continuous stress of gravity on the tendon graft at back of the tibial tunnel, which makes excessive abrasion on tibial tunnel and damaged dead center at back of the graft. The tendon graft is relatively extended and the stability of reconstruction becomes invalid. Abrasion caused by continuous stress of gravity can also works on tendon graft. There was thinning and eventual rupture of the graft with decreased tension. In 1995 Bergfeld et al. [13] designed tibial inlay technique, which was considered to be more stable biomechanically and included Arthroscopy and knee cut technique and gained good clinical effect at the follow-up. This technology can minimize the abrasion between the graft and the tunnel walls. However it requires wide incision inside and back of the knee, the incision of Posterior capsule and the changing position of during operation, which makes inconvenient maneuver and extend the operating time, thus increasing the difficulty of operation and consequent damage.

Dual-bundle reconstruction of posterior cruciate ligament is performed using full arthroscopic tibial inlay technology by self-designed tibia tunnel drilling system. An autogenous quads tendon and patellar is used with the aims to reduce the risk of possible damage caused by cutting the tissue at the back of the knee, minimize the inconvenience of body position changes and shorten the operation time. Depth-limited bone tunnel can be produced by the tibia tunnel drill system with arthroscopy for the smooth slide of bone block around femoral intercondylar. Arthroscopic tibial inlay and traditional tibial inlay for posterior cruciate ligament reconstruction are analyzed retrospectively and patients who had a minimum 1-year follow-up were included in the study. The Lysholm knee score, IKDC rating and the posterior drawer test were observed to compare the operation between arthroscopic tibial inlay and traditional tibial inlay.

Material and methods

Basic resources

From May 2007 to October 2009, 32 patrents were randomly divided into experiment group and control one. 17 PCL injured patients who had received full arthroscopic dual-bundle PCL reconstruction by improved tibial inlay technique and who also had a minimum 1-year follow-up were included in the experiment group with 9 left knees and 8 right knees, including 16 males and 1 female, with an average age of 25 years, ranging from 19 to 54. The Lysholm knee score of preoperative was 53.4 ± 2.1 points. Of all the cases, International Knee Documentation Committee (IKDC) rated C in 7, D in 10, and posterior drawer test is positive (+) in 17, with combined injury of medial meniscus in 4 cases and lateral meniscus in 7 cases. The time span between injury time and operation time was 67-256 days, with an average of 47.5 days. 15 PCL injured patients who had received full arthroscopic dual-bundle PCL reconstruction by traditional tibial inlay technique and who also had a minimum 1-year follow-up were included in the control group, including 13 males and 2 females, with an average age of 27 years, ranging from 20 to 52. The Lysholm knee score of preoperative was 52.4 ± 1.9

Figure 2. After trimming of the quadriceps tendon and the patella bone, two endobuttons with 40 mm ansa was applied to fix. One EndoButton's ansa passed through the central hole of patella bolt, of which the censa terminal passed through four 2 × 519 Ethibond lines in order to connect another EndoButton which was fixed in the outside of tibia tunnel.

points. Of all the cases, International Knee Documentation Committee (IKDC) rated C in 6, D in 11, and posterior drawer test was positive (+) in 17. Option of the patients: 1) Knee swelling and stress pain, positive posterior drawer test with Degree III. 2) The MRI shows incomplete PCL and bending ACL. Contraindication for surgery: combined knee injury and knee operation history. 3) Severe osteoporosis.

Arthroscopic tibial inlay technology with tibia tunnel drilling system

Preparation of graft for PCL reconstruction: At 90° of knee flexion, a longitudinal incision was made from the top edge 4 cm to the bottom 2 cm of the patellar (beginning at the superior pole of the patella and extended approximately 5 cm proximally). Quadriceps tendon with patellar block was collected, patellar size 15 mm × I5 mm × 10 mm, Quadriceps tendon 70 mm long and 15 mm wide, see **Figure 1**. The patellar was trimmed to be an oblique cylinder of 15 mm diameter and 10 mm high with the anatomy slope at the superior pole of the patella. A hole was drilled through the center of the patellar vertically with 3.2 mm diameter. Quadriceps tendon was split into two bundles of anterior lateral bundle of 7 mm diameter and posterior medial bundle of 6 mm. The tendon is sutured together 30 mm at the bottom. See **Figure 2**.

The tibia tunnel drilling system: The drilling system consists of three parts: 1) Drill bit, Hexagonal cylinder shape with Diagonal distance of 15 mm and height of 6 mm. the front is the smooth surface and the back is the cutting surface. The drill has six cutting teeth arranged by clockwise with 45° teeth tip, 60° cutting angle. The central hole has a 5 mm diameter and a depth of 3 mm with positive screw. The side face is designed with a hole of 3.5 mm diameter to fix the guide wire, see **Figure 3A**. 2) Drill shaft, 5 mm diameter and 150 mm long with a positive screw of 6 mm long at the top, see **Figure 3B**. 3) The drill holder, with an ellipse shape at the top, which has a 70° bending curve at the 50 mm to the top for fixing the bone temporarily, see **Figure 3C**.

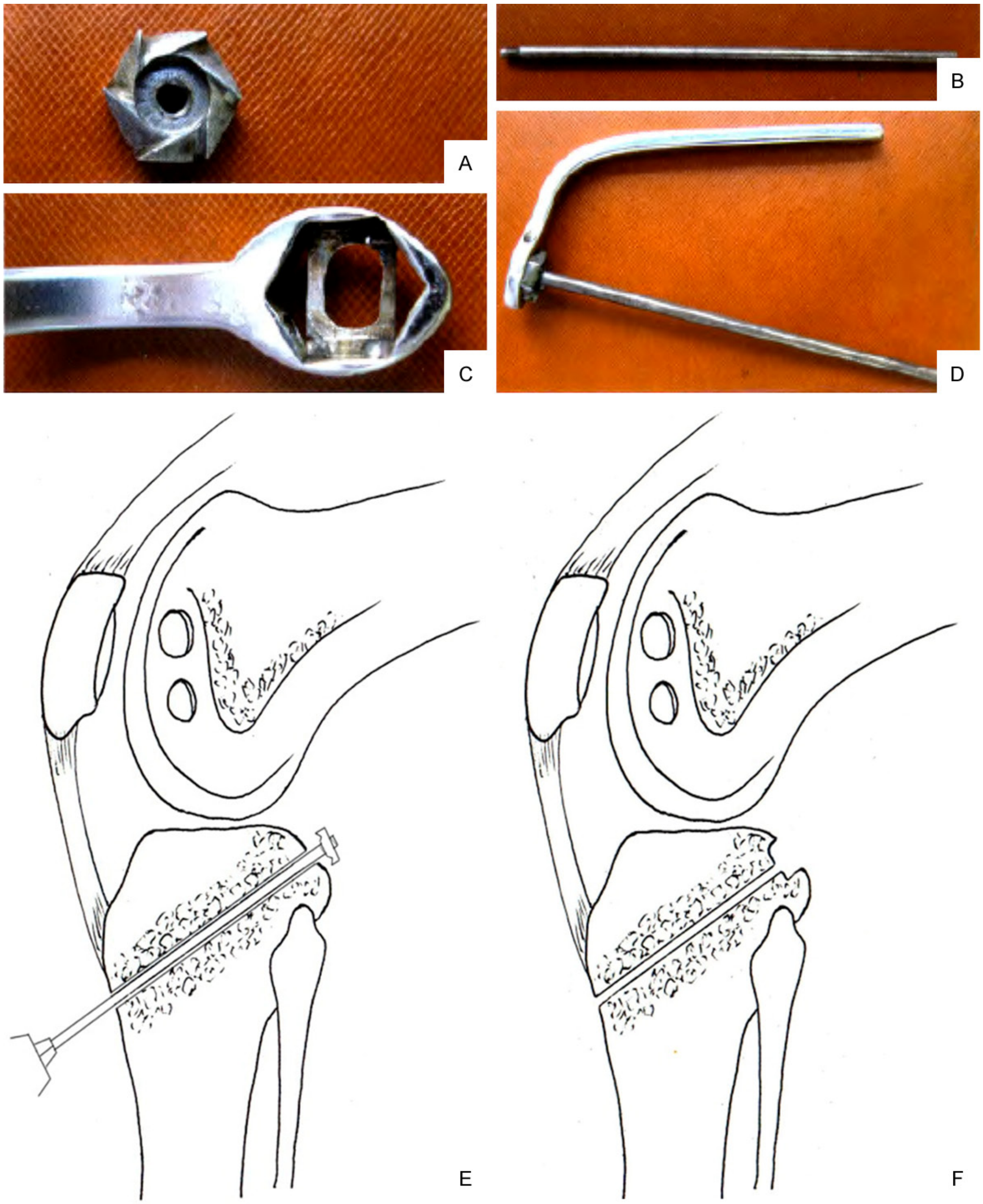

Figure 3. The tibia tunnel drill system. A. The drill; B. Drill shaft; C. Drill holder; D. Completion of the drilling tool assembly system; E. Production of the tibial tunnel; F. Finished tibial tunnel.

The drill shaft is screwed into the hole of the drill bit and pulled back out to complete the assembly, see **Figure 3D**. The drill shaft is driven by power drill by clockwise so that the drill can cut the bone underneath. By drilling the tunnel until the point at which the posterior cortex is encountered, the drill shaft is lift up and the drill bit is put into the drill holder. The drill shaft is rotated in the opposite direction to take off the drill bit. A tibia tunnel is completed with a diameter of 15 mm and depth of 6 mm, see **Figure 3E**, **3F**.

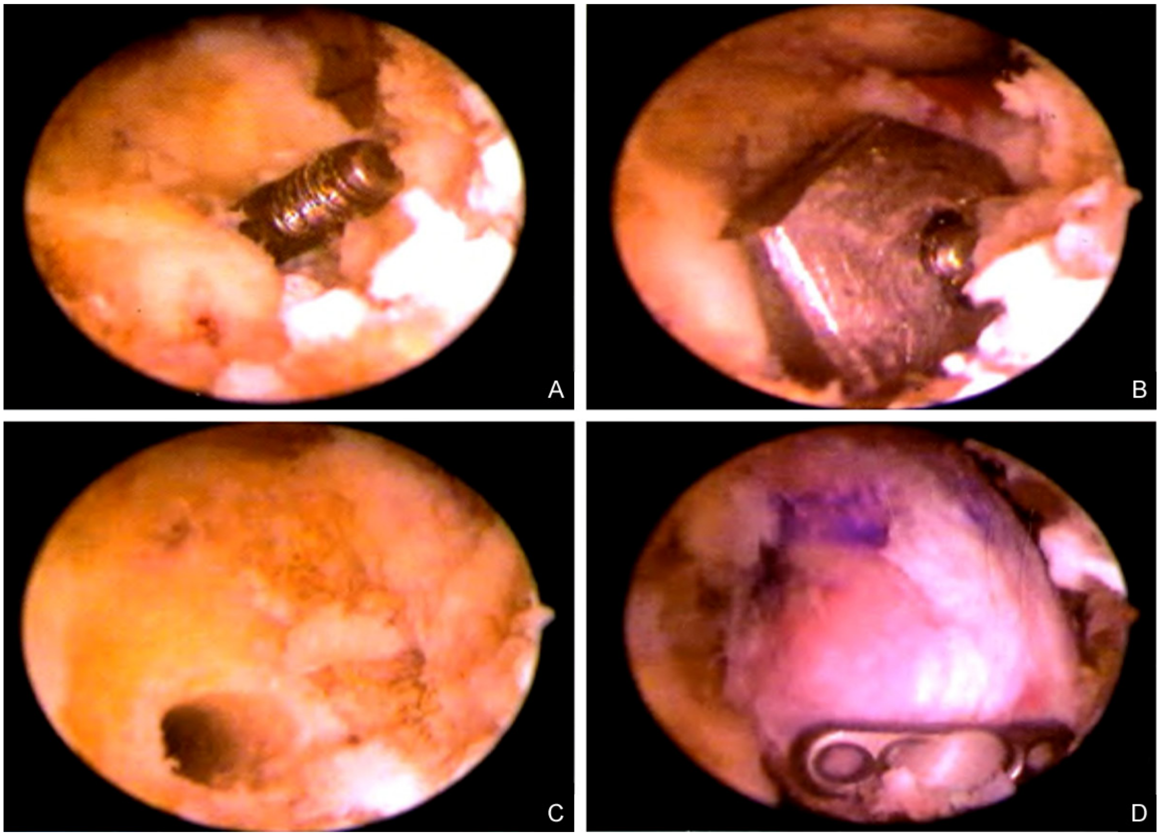

Figure 4. The arthroscopic surgery. A. Drill shaft in the tibial tunnel; B. Completion of the drilling tool assembly system; C. Finished tibial tunnel; D. Graft bone plug into the tunnel was fixed.

Arthroscopic operation: With the knee flexion of 90° a 1 cm incision is made both sides at the inferior pole of the patella until the point at which the knee capsule is encounter. An arthroscope is placed for diagnosis. Longitudinal meniscus tear is sutured and oblique tear is removed. An arthroscope is placed through the anteromedial and anterolateral portal of ACL onto the posteromedial and posterolateral margin of the knee capsule. The posteromedial and posterolateral tunnel is produced and an arthroscope tube with diameter of 8 mm is placed. The arthroscope is placed through the posteromedial incision and RF blade is placed through the posterolateral incision. The posterior gap of the joint capsule is removed to free the posterior capsule and the dead center behind PCL tibia is dissected to free the portion behind tibia.

Location of the tibial tunnel: Our preferred location is just medial to the tibial tuberosity. A 5 cm longitudinal incision is placed approximately 1 cm distal to the medial of the tibial tuberosity. A locating guide is placed through the anteromedial incision of the tibial directed by guide arm. A 5 mm holy drill is used to extend the tunnel, and with security by the protector the tip of the guide passes into the shaft protected by the protector, see **Figure 4A**. The drill holder and drill bit were placed through the anteromedial incision of the knee joint and assembly were finished in the capsule of the posterior knee, see **Figure 4B**. The drill shaft is pulled down and attached to the power drill, which cut the posterior cortex of the tibia clockwise until the drill bit is in line with the bone surface, see **Figure 4C**. The drill shaft is lift up, then the drill bit backs off the tunnel and is put into the drill holder again. The drill shaft is rotated in the opposite direction to take off the drill bit.

Two femoral condyle tunnels: With the left knee at 90° flexion, the positioning of the medial femoral condyle is according to the clock with the anterolateral tunnel at 11 o'clock and posteromedial tunnel at 8 o'clock. The guide arm of the locator is placed through the anteromedial incision of the knee. The central point of the

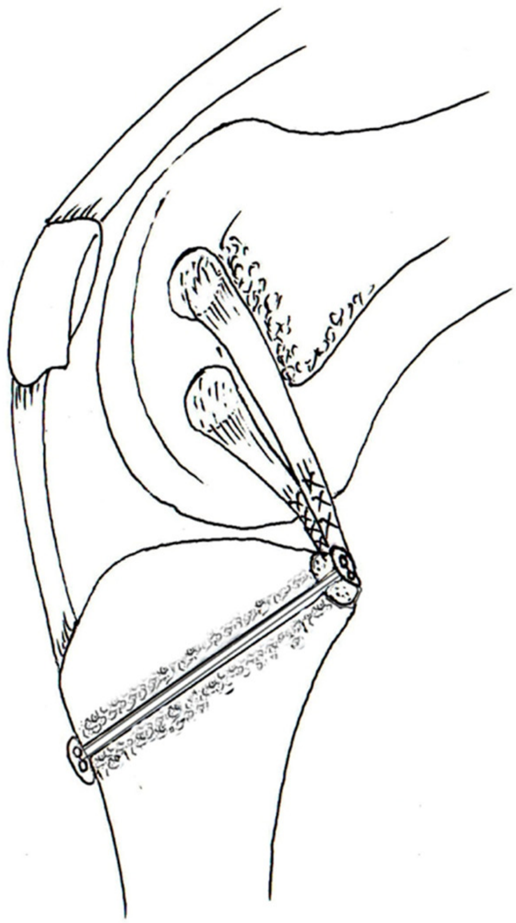

Figure 5. Postoperative sketch diagram of posterior cruciate ligament.

tunnel is 6 mm distant to the distal cartilage of the medial femoral condyle. With the drilling of the guide at 90° into the knee, a 7 mm holy drill is used to extend the tunnel. The anteromedial tunnel is produced using the same procedure with a diameter of 6 mm and a gap of 6 mm between the bone walls of two tunnels.

The fixation of graft: A guide wire is placed through the anteromedial incision of the tibia until the lateral tibial tunnel is encountered. A grasper is inserted through the anteromedial incision of the knee to guide the guide wire out of the incision. The assembled pulling thread of the bone block end then is passed through the wire and pulled out through the tibial tunnel and pull the graft into the knee hole. The rough surface of the patellar bone block is oriented to the medial femoral condyle and the tedious portion is oriented to the ACL. The patellar bone block passes through the gap between the medial femoral condyle and ACL into the lateral tunnel of the tibia. The graft tension is adjusted for the slide of the bone block into the tunnel. The pulling wire of the anteromedial tibial is pulled to pass the second mini-steel-plate and tied to fix the plate onto the wall of the anteromedial tibial tunnel. The tailed wire is fixed to the inferior tibial tunnel using a gate-shaped nail. The bone block then is fixed in the oval tunnel of the lateral tibia.

Two femoral condyle tunnels graft fixation: With the knee at 90° flexation the guide wired is inserted into the knee through the medial femoral condyle tunnel and pulled out through the anteromedial incision of the knee. Two bundles of the graft are placed in the femoral condyle tunnel separately. With the anterior drawer situation of the knee, an interference screw is passed through the medial femoral condyle to fix the two bundles of the graft. See **Figure 5**.

PCL operation by traditional tibial inlay technique

Tendon is harvested by the same procedure, so is the fixation of femoral end. The bone block is fixed with screw in the lateral incision with floating body position.

Postoperative care

The whole leg is wrapped for 7 days by Elastic bandages and fixed at 0° position for 3 weeks. The leg muscle exercises are begun at the first day postoperatively. Knee flexion exercises from 0° to 45° are begun at four weeks. Full weight-bearing with the knee in extension is allowed at 7 weeks and the knee flexion gradually progressed to 90°.

Follow-up and clinical evaluation

During operation, two kinds of operation were evaluated by blood loss, operation time and complications of nerve or vascular injury. Clinic follow-up is performed after 3 months, 6 months, 1 year and 2 years of operation. The location of the bone block and the healing situation were checked by knee X-ray and spiral CT scan. At the final follow-up, the Lysholm knee score, IKDC rating and the posterior drawer test were evaluated.

Statistical handle

SPSS 12.0 is used to handle the result statistically. Blood loss, operation time and the

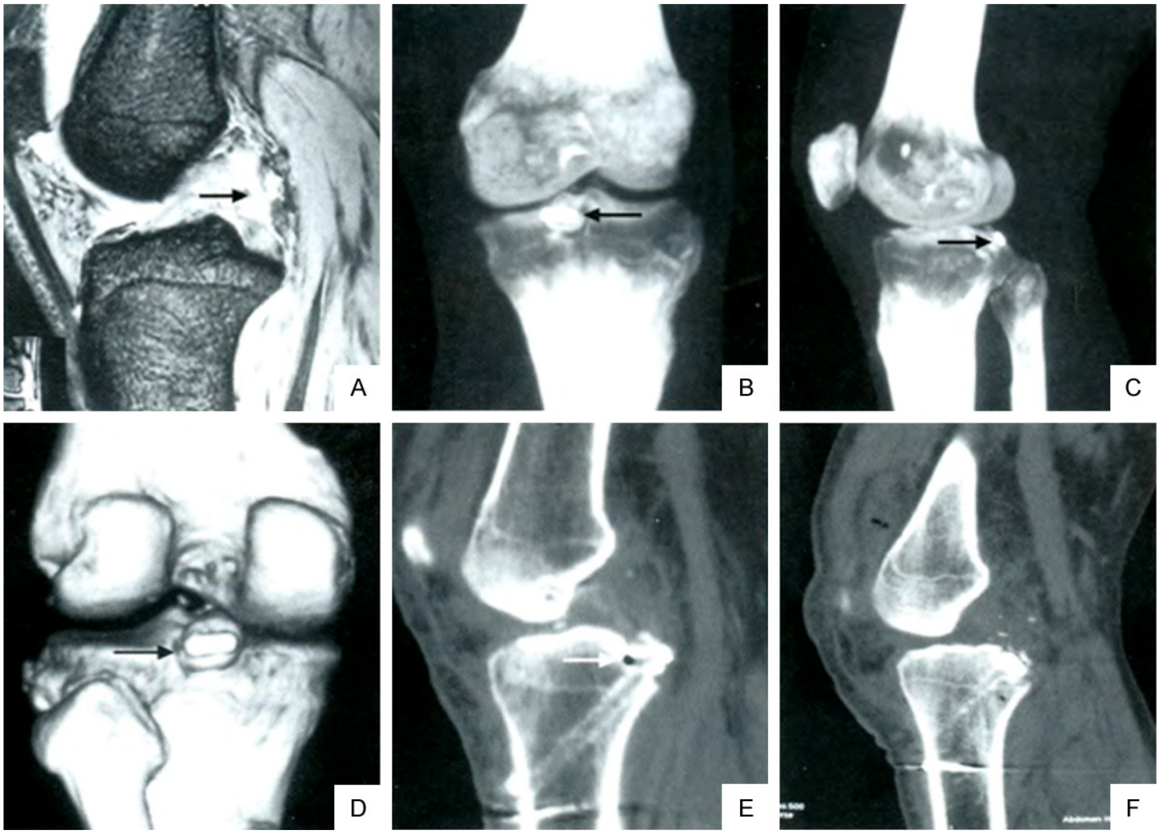

Figure 6. A 46-year-old male, arthroscopic reconstruction of posterior cruciate ligament tibial inlay techniques. A. Preoperative MRI showed PCL injured; B, C. Postoperative X-ray films showed the location of bone block; D, E. Postoperative CT showed the location of the bone block; F. CT 12 weeks after the operation showed the bone block was healed.

Lysholm knee score are compared between the two techniques and IKDC rating was performed by two-sided Chi-square test ($\alpha = 0.05$). The score is represented by mean value ± standard deviation.

Results

Diagnosis by arthroscopy in all cases was consistent with the preoperative with successful operation procedure. The incision healed during the first period and the stitches were removed after 12 days postoperatively with no infection. The knee flexed to over 90° with extension in 0°. All the patients were followed up from 12 to 28 months, with an average of 17.8 months. Mean intraoperative blood loss was 123.53 ± 74.05 ml in the improved tibial inlay group compared with 332 ± 114.26 ml in the traditional tibial inlay group ($t = 6.12$, $P < 0.05$). Mean operation time was 235.27 ± 58.88 min in the improved tibial inlay group compared with 346.37 ± 59.67 min in the traditional tibial inlay group ($t = 5.19$, $P < 0.05$). There was one case complicated with tibial nerve injury and another with popliteal vein injury in traditional tibial inlay group, who were respectively healed by vascular anastomosis, neurotrophy drugs and rehabilitation. However, there was no case in improved tibial inlay group.

The Lysholm knee scores showed a significant improvement of 40.1 ± 1.9 points, up to 93.5 ± 1.7 at the final follow-up using improved tibial inlay technology. Statistically significant difference was found as compared with preoperative data ($t = 0.024$, $P = 0.016$). IKDC rating of A grade in 15 cases, B in 2,compared with that of preoperative was statistically significant different ($P = 0.021$). Posterior drawer test were negative in 15 cases, slight positive in 2. The Lysholm knee scores showed a significant improvement of 41.8 ± 0.3 points, up to 94.2 ± 1.2 at the final follow-up using traditional tibial inlay technology. Statistically significant difference was found as compared with preoperative data (t = 0.021, *P* = 0.014). The Lysholm knee scores showed no significant differences between the 2 techniques (p = 2.11). IKDC rating was A grade in 16 cases, B in 1 using traditional tibial inlay, with statistically significant difference compared with preoperative data (X^2 = 0.03, P = 0.019). IKDC rating showed no significant differences between the 2 techniques (p = 8.67). Posterior drawer test were negative in 14 cases, slight positive in 1. The X-ray and spiral CT scan of the second after operation showed the location of the bone block were perfect and healed well with the patents two weeks later (**Figure 6**).

Discussion

Several steps of conventional tibial inlay technique may make unsatisfactory results. First of all, a posterior operation incision described by Burks as posterior straight incision or posteromedial incision is needed for the showing of the posterior edge of the tibia [11]. The posterior tissues include the posterior capsule, oblique popliteal ligament, etc. Recent studies showed that removal of the posterior capsule would affect the posterior laxity at any degree of knee flexion [12]. The operation requires 1 or 2 times of body position changes are required, which will extend the operation time. It makes it not easy to make a posteromedial incision with the floating body position for even the most experienced doctors. Bone block of the graft may fractures during the process of fixing the screw, which is another problem. Finally, conventional tibial inlay technique is limited by many factors including: the steel plate and the screw surrounding the tibia will affect the fixing of the posterior bone block; surgery scar caused by knee dislocation combined with vascular injury will affect the showing intraoperatively [14-16]. In this study, a self-designed tibia tunnel drilling system by arthroscopy is used to make oval bone tunnel for the smooth slide of bone block around femoral intercondylar. The postoperative evaluation showed no statistical difference of the knee stability between the two techniques. The MRI showed the location of the bone block was perfect and healed well with the patents, suggesting this operation method is reliable with good clinic results recently.

Arthroscopic Inlay technique facilitates the surgical procedure and reduces the surgical trauma without posterior incisions of the knee and intraoperative changes of the body position [17, 18]. However, he makes a tibial tunnel from anterior to posterior with length equaling to diameter, which can hold the whole block, but cannot constrain the bone block to the location in the tunnel correctly and cannot guarantee avoiding being stressed of the tendon at the back of the tibia tunnel, which results in the "killer turn". The most portion of the bone block in the tunnel is loose which is vulnerable to be broke when fixed with screw. In our study, the patellar block is an oblique cylinder which keeps the connection part between tendon and the bone. The depth of the tunnel is limited so that the bone block will not be pulled into the tunnel excessively, which avoids the "killer turn". Pressure can be evenly distributed by EndoButton because of the hard surface of bone block, which can prevent EndoButton ansa to damage bone bolt mesopores.

Arthroscopic Inlay technique designed by Mariani et al [19] uses the traditional rectangular bone block. The bone block is thin and small, and the tunnel is shallow for the pass through the posteromedial incision of the knee. Shallow embedment will result in slide during the pulling movement, and the stitch for fixing the bone block works directly on the tunnel at back of the tibia, which make the stress concentration. Stitch or the walls of the tunnel is ruptured, the stability of the ligament reconstruction loses. In our study, the oblique rectangle bone block guarantees enough embedment depth, the kept of Anatomy slope at the superior pole of the patella guarantees the intensity of the bone block for its smooth slide into the tunnel and resistance to the pulling power of the tension by producing embedment stress by pulling of the guide wire. The tibial inlay technique designed by Ruberte Thiele etc. [20] use rectangular or cylinder bone block fixed by double-hole and double-thread or single-hole and single hole. The comparison of the biomechanical stability between the two fixing techniques showed no statistical difference with the easier pass of bone block of cylinder through narrower gap of the knee. In our study, the same volume of bone block of oblique cylinder covers more areas with the tunnel and shows no exotic instability under EndoButton system.

This study can provide another operation for patients with PCL rebuilding. However, the number of cases in this study is few, which may affect the reliability of the conclusion in a certain extent. The operation of PCL by tibial inlay technology needs further research in terms of advantage and long-term effect.

Disclosure of conflict of interest

None.

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