RESEARCH ARTICLE

The Clinical Outcome of Simultaneous Lateral Closed-Wedge Distal Femoral Osteotomy and Anterior Cruciate Ligament Reconstruction in the ACL-deficient Knees with Symptomatic Femoral Varus Deformity

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Abstract

Background: Nowadays combined high tibial osteotomy and ACL reconstruction is accepted as a safe and effective surgery for patients with symptomatic varus osteoarthritis and anterior knee instability; however, the source of varus deformity is sometimes the femoral bone. No studies have reported concomitant ACL reconstruction and distal femoral osteotomy in ACL-deficient knees with femoral varus deformity and medial osteoarthritis till now. This prospective study presents the technique and clinical outcome of a consecutive series of simultaneous lateral closed-wedge distal femoral osteotomy and ACL reconstruction.

Methods: Nineteen patients with confirmed ACL rupture and femoral varus deformity (mechanical lateral distal femoral angle ≥ 93°) associated with medial osteoarthritis (± lateral thrust) were included the study. The patients underwent simultaneous lateral closed-wedge distal femoral osteotomy and ACL reconstruction. At the end of one year follow up, the final range of motion and stability of the knees and the last alignment of extremities were recorded. Surgical outcomes were assessed on 2000 IKDS subjective scores and KOOS subscales.

Results: The mean preoperative varus knee was 10.6° (±2.2°) mostly from the femoral side. The mean union time was 3.2 (±0.4) months. Regarding the radiological evaluation, the alignment of extremity and mLDFA were corrected significantly compared to the pre-operative findings. At the end of one year follow up, all patients were free of knee instability. Subjective assessment based on questionnaires showed a significant improvement in all aspects of knee function after surgery, however there was no considerable change in the knees range of motion.

Conclusion: Simultaneous lateral closed- wedge distal femoral osteotomy and ACL reconstruction is a valuable procedure in femoral varus knees with medial osteoarthritis and anterior knee instability. After one year follow up all aspects of knee function were improved without serious complications.

Level of evidence: IV

Keywords: ACL reconstruction, High tibial osteotomy, Medial compartment, Osteoarthritis

Introduction

Anterior cruciate ligament (ACL) rupture has devastating effects on the knee structures specially the menisci (1, 2). The deterioration of knee function and repeated giving way gradually causes degenerative changes in the cartilage and meniscus especially in the medial side (3).Osteophytes formation

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takes about two years to be found in X-ray (4). The progress of degenerative changes happens faster with varus deformity of the knee and previous meniscectomy (1, 5). On the other hand, varus deformity of the knee is associated with the development and progression of osteoarthritis in the medial site of the knee (6, 7). Different types of osteotomy around the knee have been introduced aiming to the correction of the limb alignment and unloading the overloaded medial compartment of the knee to delay arthritic progression (2, 8). However, the source of a varus deformity may be localized in the tibia, femur, or both (6). If a varus deformity with femoral origin is corrected by a high tibial osteotomy, a re-aligned limb axis will be remained at the cost of an excessively oblique joint line (9). A three-dimensional (3D) finite element model analysis revealed that joint-line obliquity more than 5° induced excessive shear stress on the tibial articular cartilage (10). Lateral closed wedge valgus osteotomy of the distal femur has shown clinical improvement and accurate corrections in these patients with femoral varus deformity (6).

Nowadays combined high tibial osteotomy and ACL reconstruction is a safe and effective procedure for treatment of varus knees associated with medial osteoarthritis and anterior knee instability (2, 5, 11) but, to the best of our knowledge, no studies have yet examined concomitant ACL reconstruction and distal femoral osteotomy in ACL-deficient knees with symptomatic femoral varus deformity until now. This prospective study presents the technique and clinical outcome of a consecutive series of simultaneous lateral closed-wedge distal femoral osteotomy and ACL reconstruction in patients with symptomatic femoral varus knees and anterior knee instability.

Materials and Methods

All patients with a history of knee instability and genuvarum in the age group of 20–55 years referring to our knee clinic between March 2014 and September 2017 were selected and clinically evaluated. A complete examination of the knee stability especially Lachman and Pivot-shift test was performed and the knee was also checked for varus/valgus instability and preoperative range of motion. The presence of tenderness in the medial joint line of the knee and a varus thrust in gait assessment were considered as two strong indications for osteotomy around the knee (12). Patients with either of these symptoms underwent plain knee X-rays in four planes (AP weight-bearing view, lateral view, Rosenberg view and Merchant view) and a standing full leg AP radiograph [Figure 1]. The severity of osteoarthritis in knee compartments was scored using Kellgren and Lawrence scale (13, 14). In addition, the degree and origin of varus deformity was evaluated by measuring the mechanical tibiofemoral angle (mTFA), the mechanical lateral distal femoral angle (mLDFA), the medial proximal tibial angle (MPTA) and the joint line convergence angle (JLCA) (6). MRI was performed preoperatively to confirm ACL tear. All patients with confirmed ACL rupture, medial knee pain (± lateral thrust) and femoral varus deformity (mLDFA ≥ 93°) were included in the study [Figure 2]. The

Figure 1. Preoperative standing full leg AP radiograph reveals bilateral varus knees in middle-aged man with ACL tear in the left side.

pre-operative range of motion (ROM) and 2000 IKDC subjective score were recorded. Five subscales of the 42-item self-reported KOOS questionnaire including the pain, symptoms, ADL (Activity of Daily Living), function in sport and recreation (Sport/Rec) and knee-related quality of life (QoL) were recorded separately (15, 16).

Smoking, drug addiction, BMI >30 kg/m^2, unrepairable grade III lateral meniscus tear, history of rheumatologic disease, immunodeficiency, arthroscopic or radiological grade IV osteoarthritis in medial compartment of the knee, arthroscopic or radiological grade III or IV osteoarthritis in lateral or patellofemoral compartments of the knee, varus knee with mostly tibial origin (MPTA < 83°), and rupture of other knee ligaments were considered as exclusion criteria. Similarly, patients with history of septic knee arthritis and history of surgery around the knee except arthroscopic meniscectomy or meniscus repair were excluded. The study was approved by the local Medical Ethics Committee.

Surgical technique

A single dose of intravenous prophylactic antibiotic was used preoperatively. The patient was positioned supine on a radiolucent table with a narrow cuff tourniquet at the root of the thigh and a lateral post at the level of the tourniquet. Knee arthroscopy was performed through standard anteromedial and anterolateral portals and all parts of the knee were examined. Concomitant meniscal tears and cartilage defects were treated. With unrepairable lateral meniscus tear grade IV the degenerative changes (according to Outerbridge classification) in medial compartment and grade III/

Figure 2. Preoperative analysis of left knee AP weight-bearing X-ray demonstrates that the main origin of varus deformity is from femoral side (LDFA =94 °).

IV degenerative changes in lateral or patellofemoral compartments of the knee, the patient was excluded from the osteotomy plan (17).

Hamstring (gracilis and semitendinosus) tendons were harvested through a 3 cm incision on anteromedial surface of the proximal tibia just at the level of tibial tubercle. The minimum acceptable diameter for the allograft was 8 millimeter. Arthroscopic assessment of the knee was done through anteromedial and anterolateral approach. The medial or lateral meniscus tears were repaired or subjected to meniscectomy. When the rupture in the lateral meniscus was unrepairable or severe osteoarthritis was found in lateral or patellofemoral compartment, femoral osteotomy was stopped and the patient was excluded from the plan. Anatomical single bundle ACL reconstruction was performed according to the standard technique. Femoral tunnel was prepared through the anteromedial portal at the midpoint between anteromedial and posterolateral bundle. The tibial guide (Arthrex) was positioned at ACL footprint and the tibial tunnel was created the same size as the allograft. The quadruple hamstring graft was fixed on the femoral using suture button fixation on cortical bone (GFS II endobutton, Paracus Medical TM), whereas fixation of the graft on the tibial site was delayed until the osteotomy was completed to avoid any change in the graft tension during correction of the knee alignment [Figure 3].

The distal femoral osteotomy was performed through the lateral subvastus approach with a 10-15 cm straight lateral incision, starting 2 cm proximal to the knee joint line. The lateral surface of the distal femur was exposed with longitudinal split of the iliotibial band and lifting the muscle belly of vastus lateralis by a blunt retractor. After finding and ligation of the perforating vessels, the second

Figure 3. Surgical technique (left knee): The hamstring graft was fixed on the femur using suture button fixation, whereas fixation of the graft on the tibial site was delayed until the osteotomy was completed. The remnants of sutures were used to find and keep the endobutton safe.

blunt retractor was placed posteriorly in contact with the bone to support the popliteal neurovascular bundle. The button was found on the lateral cortex. Under fluoroscopic guidance a 2.5 mm K-wire was inserted just proximal the button, along the plan of the osteotomy from proximal-lateral to distal-medial direction, aiming at the adductor tubercle and nearly perpendicular to the mechanical axis of femur [Figure 4]. Osteotomy was started just proximal to the K-wire [Figure 5]. An oscillating saw with thin

Figure 4. Surgical technique (left knee, lateral view). The button could be found on the lateral side of the distal femur. A guidewire was inserted just proximal to the button, along the plan of the osteotomy from proximal-lateral to distal-medial direction, aiming at the adductor tubercle. A distal femur plate was used to protect neurovascular structure.

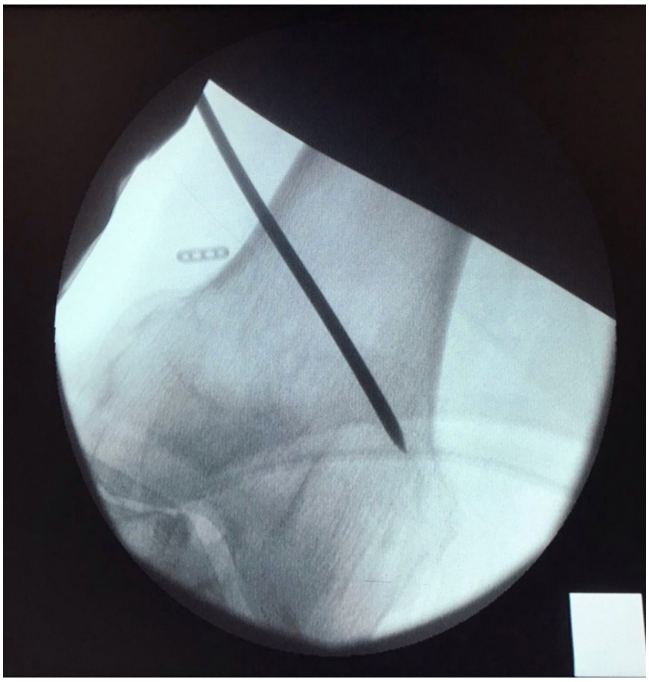

Figure 5. A 2.5 mm K-wire was inserted just proximal to the button, along the plan of the osteotomy, aiming at the adductor tubercle and under fluoroscopic guidance.

blade was used to perform a close-wedge osteotomy from lateral to medial direction while the quadriceps tendon and posterior neurovascular structures were protected. A bony wedge was removed from the lateral cortex without breaking the medial cortex .The wedge thickness was considered in millimeters equal to half the angle desired for correction in degrees.

The gap was gently closed by valgus stress applied to the limb with a fulcrum at the level of the osteotomy. It might take several minutes to induce plastic deformation of the medial cortex to close the osteotomy gap without breakage. It should be considered that the medial cortex of the distal femur is weaker than the lateral cortex of the proximal tibia in a medial closing-wedge osteotomy and it is more likely to break the hinge point of distal femoral osteotomy(6). Acceptable rotational and axial stability can be obtained by an intact medial cortex. The mechanical axis of the lower limb was checked under fluoroscopy using a long rigid alignment rod (between the center of femoral head and the center of talus dome) to ensure the correction of the varus deformity. The rod should pass through the knee joint just lateral to intercondylar spine. When the desired correction was achieved, fixation could be performed with LCP distal femur plate 4.5 mm (Osveh Asia Medical Instrument Company).

The plate was placed on lateral side of the distal femur. After drilling, at least two monocortical locking screws were inserted distal to the osteotomy side and one bicortical self-tapping cortical screw proximally. The plate position was then checked by fluoroscopy. Next, a bicortical lag screw was inserted eccentrically in the dynamic part of the hole directly superior to the osteotomy site to induce axial compression at the cutting interval. All screws were positioned except for the distal posterior cancellous screw to avoid damage to the EndoButton. After completion of fixation, the final checking was performed by fluoroscopy.

The ACL graft was tensioned while the knee was moved through full range of motion for 20 cycles. Then tibial fixation was performed with a bioabsorbable screw at 30° knee flexion (biocomposite interference screw, Arthrex). Arthroscopic examination of the knee was performed again to rule out graft impingement. The limb circulation was controlled after the tourniquet was released. The fascia lata, subcutaneous tissue, and skin were closed meticulously over a non-suction drain at the osteotomy site. After closing the donor site, a sterile compressive bandage and a knee immobilizer was applied.

Isometric quadriceps exercise, ankle pump, straight leg exercise was started as soon as possible. Full active and passive range of movement of the knee was allowed when the patient could tolerate. The drain was removed and the patient was discharged the day after surgery. Patients were visited at 1, 3, and 6 weeks, and 3, 4, 5, 6 and 12 months after surgery and evaluated for complications of osteotomy and ACL reconstruction. The union of osteotomy site was assessed at 6 weeks, 3, 4, 5, 6 and 12 months after osteotomy by standard anteroposterior and lateral views of the knee. During the first 6 weeks the patient could walk with two crutches (partial weight-bearing). Progressive full-weight bearing was allowed when clinical and radiographic signs of bone healing were determined usually at 6 -8 weeks [Figure 6].

At the end of 12 month follow up, the last range of motion of the knees was noted and their stability was evaluated by Pivot- shift and Lachman tests. The final alignment of extremities and the mechanical lateral distal femoral angle (mLDFA) were measured on standing full leg AP radiographs .The surgical outcomes were assessed on 2000 IKDS subjective scores and KOOS subscales.

Data were analyzed by SPSS software version 19. The descriptive data were expressed as mean ± standard deviation. Statistical tests used included Chi-square, Kolmogorov-Smirnov and paired t-tests. In this study, *P-value <0.05* was considered as statistically significant.

Results

Nineteen patients with ACL deficiency and femoral varus deformity of the knee underwent simultaneous anatomic ACL reconstruction and valgus osteotomy from the femoral side. The median age at the surgery was 37 (±5.2) years. The mean body mass index of the patients at surgery time was 27±3.2 kg/m^2 .All patients were men and complained of medial knee pain. Lateral thrust was found in 8 knees before the surgery.

The mean preoperative varus knee was 10.6° (±2.2°) mostly from the femoral side. Table 1 shows the

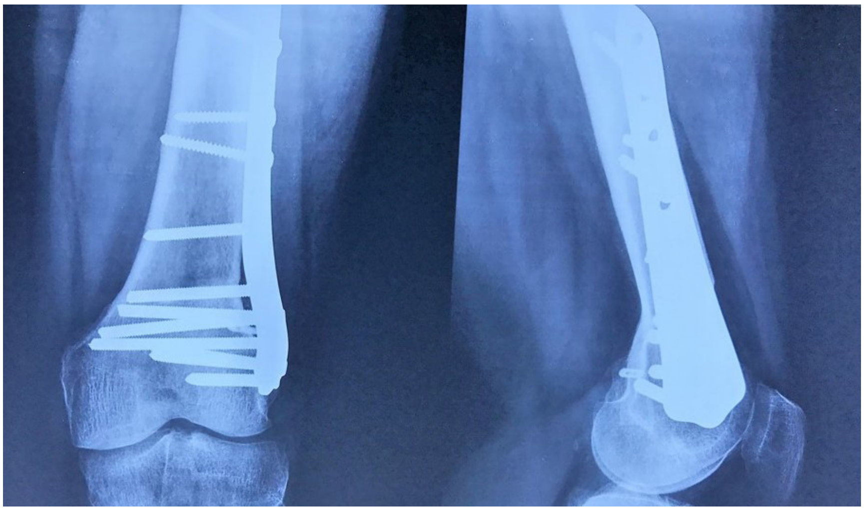

Figure 6. Postoperative radiographs 6 weeks after surgery. The button can be demonstrated on the lateral side of the distal femur.

preoperative radiologic characteristics of the study population. All patients had some degrees of osteoarthritis in the medial compartment preoperatively while some cases had mild osteoarthritis in patellofemoral surface and lateral compartment of the knee [Table 1].

In arthroscopic evaluation, twelve knees (63%) had medial meniscus tear, leading to partial meniscectomy in nine cases and meniscal repair in three knees. There was no lateral meniscus injury in the knees. All cases had degenerative changes in the medial compartment. According to Outerbridge classification, in ten knees grade III, in three knees grade II, and in six cases grade I cartilage lesions were found in the medial side. Eleven knees in the patellofemoral surface and five knees in the lateral compartment had grade I cartilage lesions.

Table 1. Preoperative radiologic characteristics of the study group	
The mean preoperative varus knee (±SD)	10.6° (±2.2°)
The average lateral distal femoral angle (±SD)	94.9° (±1.1°)
the average medial proximal tibial angle (±SD)	85.1° (±1.3°)
the average convergent angle (±SD)	1.7° (±1.6°)
Kellgren and Lawrence scale in medial compartment	
Grade 0 [n (%)]	0
Grade 1 [n (%)]	5 (26.3%)
Grade 2 [n (%)]	8(42.1%)
Grade 3 [n (%)]	6(31.5 %)
Kellgren and Lawrence scale in lateral compartment	
Grade 0 [n (%)]	16(84.2%)
Grade 1 [n (%)]	3(15.8%)
Kellgren and Lawrence scale in patellofemoral surface	
Grade 0 [n (%)]	8(42.1%)
Grade 1 [n (%)]	10(52.6%)
Grade 2 [n (%)]	1(5.2%)

At the end of four months all patients showed union at osteotomy site. The mean union time was 3.2 (±0.4) months. Regarding radiological evaluation, the alignment of extremity and mLDFA were corrected significantly at final standing full leg AP radiographs when compared to the pre-operative findings. The mean postoperative varus knee angle and mechanical lateral distal femoral angle were -1.5° (range 4°valgus -2 °varus) and 84.5°(range 82-90°), respectively.

All patients were free of knee instability at the end of one year follow up and Lachman test was negative in all knees. The Pivot-shift test was negative in 16 cases and slide (grade1) in three. Subjective assessment based on 2000 IKDC subjective knee evaluation form and KOOS questionnaire showed a significant improvement in all aspects of knee function after surgery, however there was no considerable change in the range of motion of the knees [Table 2].

Discussion

Combined ACL deficiency and varus knee deformity is not an uncommon complaint. There is an ongoing debate on whether ACL reconstruction and varus correction is to be performed sequential or simultaneous (18, 19). There is a direct relationship between varus malalignment and ACL tension (20). Varus alignment of the knee may increase axial pressure of the medial compartment and enhance tension on the lateral structures as well as ACL (21, 22). On the other hand, chronic ACL tear induce medial meniscus tear leading to degenerative changes in medial compartment and increasing varus deformity especially in cases with lateral thrust (2, 6, 7). Therefore, it looks better for knee

Table 2. comparison between the pre- and postoperative ROM of the knees and clinical outcome scores

	Pre- operation	final follow up	*p- value**
Mean max knee flexion	138.6° ± 8.7°	136.3°± 8.3°	*P=0.226*
Mean max knee extension	5.7° ± 6.2°	2.8° ± 3.8°	*P=0.115*
Mean max knee ROM	132.8° ± 10.9°	133.4° ± 9.7°	*P=0.828*
Mean IKDC	61.6 ± 7.5	86.2 ± 5.4	*P< 0.001*
Mean KOOS subscales			
Pain	56.8 ±9.1	83.8±6.5	*P< 0.001*
Symptoms	53.3±6.7	86±6.3	*P< 0.001*
ADL	64.1±6.2	87.1±6.1	*P< 0.001*
Knee related QoL	45.2±11.7	83.4±7.2	*P< 0.001*
Sport /Rec	48.6±6.1	84.1±7.3	*P< 0.001*

*Significant values (*P<0.05*)

function to perform ACL reconstruction and corrective osteotomy simultaneously (19).

Routinely, the correction of varus deformity is usually performed in the proximal tibia, but, there are some varus knee cases due to distal femoral deformity (9, 23). If varus deformity is localized within the femur, it is necessary to correct it in the femur (6). In these patients, high tibial osteotomy may correct the extremity alignment at the cost of an excessively oblique joint line. Nakayama and his colleagues using a three-dimensional (3D) finite element model analysis demonstrated that joint-line obliquity more than 5° could induce excessive shear stress in the tibial articular cartilage (10). Van der Woude *et al* represented that lateral closed-wedge valgus osteotomy of the distal femur could elicit clinical improvement and accurate corrections in these patients with femoral varus deformity (6).

Nowadays combined high tibial osteotomy and ACL reconstruction is accepted as a safe and effective procedure for treatment of patients with symptomatic varus osteoarthritis associated with anterior knee instability (2, 5, 11). Jin *et al* in a retrospective study collected 24 patients who were diagnosed with ACL injury and medial compartment OA with varus deformity that underwent combined open-wedge HTO and ACL reconstruction. After 5 years follow-up, there were no limitations in range of motion and nonunion in the sample while the functional knee scores were significantly improved after surgery (24). Trojani *et al* in another retrospective study revealed that concomitant ACL reconstruction and valgus HTO could relieve pain in 70% of cases and restore knee stability enabling return to sport in 80 % of the patients (25). In a case series with 32 patients and a mean of 6.5 years follow-up Zaffargini *et al* concluded that concomitant HTO and ACL reconstruction allowed patients with medial OA, varus alignment and chronic ACL deficiency to restore normal knee stability and alignment and resume a recreational level of activity. No patients underwent osteotomy revision, ACL revision, or arthroplasty during the follow-up (26).

No studies have been conducted on concomitant ACL reconstruction and distal femoral osteotomy in ACL-deficient knees with symptomatic femoral varus deformity so far. This prospective study presents the novel technique of simultaneous surgery and the clinical outcomes of a consecutive series of patients with symptomatic femoral varus knees and anterior knee instability who underwent the surgery. The combined surgery has the cumulative advantages of each surgical procedure together with a faster recovery compared with a staged procedure but requires more training and longer rehabilitation. In our prospective study, all patients had union in the osteotomy site with acceptable knee range of motion without subjective instability in the knees at the end of one year follow up. Subjective assessment of the patients with IKDC and KOOS questionnaires showed a significant improvement in all aspects of knee function after the surgery.

It is necessary to mention that there is a risk of interference between the tibial tunnel and the proximal tibial cut in the simultaneous HTO and ACL reconstruction surgery that may lead to failure of ACL graft fixation on the tibial site (27). However, the location of femoral osteotomy and ACL reconstruction is completely separate in our recommended surgery and there is no interference between these two surgeries.

Our study has some limitations. First, the sample is too small to draw any definitive conclusions about the outcomes of this combined procedure. Second, one-year follow-up may be short to evaluate the outcomes of this salvage procedure; however, no serious complications were found in this period. Third, all patients were male, and finally, since this procedure was novel and performed for the first time, there was no control group for comparison .We had to compare our results with the available literature about combined high tibial osteotomy and ACL reconstruction. The next step would be a well-designed study with adequate sample and long term follow up.

Based on the results of this study, simultaneous lateral closed-wedge distal femoral osteotomy and ACL reconstruction is suggested as a valuable procedure in patients with symptomatic femoral varus knees and anterior knee instability. After one year follow up all aspects of knee function improved without serious complications.

Conflicts of interest: The authors declare that no financial or material support of any kind was received for the work described in this study.

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