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Original Article

Posterior femoral translation in medial pivot total knee arthroplasty of posterior cruciate ligament retaining type

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ABSTRACT

Purpose: To report clinical results and demonstrate posterior femoral translation (PFT) in medial pivot total knee arthroplasty (TKA) of posterior cruciate ligament (PCL) retaining type. **Materials and methods:** A prospective study was performed upon thirty consecutive subjects who were operated on with medial pivot TKA of PCL retaining type between March 2009 and March 2010 and had been followed up for at least 2 years. Clinically, the knee society knee score and function score were used. In full extension and active flexion lateral radiograph, anteroposterior (AP) condylar position and magnitude of PFT was determined. **Results:** At last follow-up, the mean knee society knee score and function score improved significantly compared to preoperative scores. The AP condylar positions were consistently posterior to midline throughout the entire range of flexion. The PFTs averaged 0.31 (± 0.12) of half length of tibial base plate and were greater in higher flexion cases ($r = 0.56$, $p = 0.0012$). There were no cases having either component migration or radiolucent line wider than 2 mm except for one case showing instability related to trauma.

Conclusions: In medial pivot TKA of PCL retaining type, clinical outcomes were satisfactory and posterior femoral translations were consistently observed during progressive flexions of knees at two- to three-year follow-up.

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1. Introduction

The primary goal of total knee arthroplasty (TKA) is relief of pain which has been well achieved nowadays by modern implants. However, the restoration of knee function, esp. kneeling also become one important parameter in evaluating outcome. The TKA of medial rotation type was intended to recreate normal knee kinematics.¹ The single spherical curvature of femoral component and asymmetrical tibial polyethylene insert are characteristic in this type of TKA implant.

The original medial pivot design was designed not to presume femoral rollback² and so fully conforming in that medially stable conformity confers anteroposterior (AP) stability throughout range of motion and posterior rolling of femoral condylar component is only allowed in lateral compartment.¹ Less conforming design with 'double high' tibia insert was introduced to enhance femoral rollback in posterior cruciate ligament (PCL) retaining condition.

We hypothesized that posterior femoral translation (PFT) would be demonstrated in medial as well as lateral side and

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greater in cases with higher flexion of knee. Recently there have been some reports concerning PFT of medial rotation TKA prosthesis³⁻⁵, but each of them was complex kinematic study requiring expensive 3-D analysis performed *in vivo* or using cadaveric model. So, our study was designed to ascertain whether PFT would occur in medial rotation TKA of PCL retaining type with just quantitative measurements of AP condylar positions obtained in active knee flexion lateral radiographs and report clinical and radiological results in thirty consecutive series.

2. Materials and methods

2.1. Patients

This study is a pre-planned longitudinal cohort one based upon radiographic analysis of thirty consecutive TKA cases which were performed from March 2009 to March 2010 and could be followed up until February 2012. Inclusion criteria were age between 60 and 75 years and primary degenerative joint disease of knee graded as Kellgren Lawrence grade III or higher. Exclusion criteria were age under 60 years or over 75 years, any inflammatory joint disease including rheumatoid arthritis, early stage of primary degenerative joint disease of knee or any history of previous osteotomy around knee. Each case was replaced with ADVANCE Medial Pivot prosthesis (Wright Medical Technology, Arlington, TN, USA). This prosthesis has two different designs of the polyethylene insert: one is the standard medial pivot (MP) design and the other is the double high (DH) design (Fig. 1). We used DH design in all cases preserving PCL to facilitate femoral rollback during the flexion of knee and all operations were performed by one surgeon (SHC) and could also ascertain some degree of PFT intraoperatively (Fig. 2A and B).

2.2. Measurement

Radiographs were made preoperatively and postoperatively immediately, 2-week, 3-month and 6-month intervals, and included AP, lateral, Rosenberg view and Merchant view. On last follow-up radiographs, the position of components and the presence as well as the location of any radiolucent line surrounding the implant were observed, and lower extremity scanogram was taken to measure lower limb alignment. Laidlaw et al⁶ reported that an active flexion lateral radiograph would provide a simple inexpensive quantitative measurement of tibiofemoral AP position and active knee flexion, correlating well with similar information from more complex *in vivo* fluoroscopic kinematic studies. We assumed that there would be also some PFT in medial femoral condyle of medial pivot TKA prosthesis under PCL retaining condition. So, if we took true lateral views with complete overlap of the medial and lateral femoral condyles both in full extension with the leg externally rotated and in full active flexion with the leg internally rotated, we could consider the measured PFT as an approximation of PFTs of both femoral condyles although each of these translate in different amount from full extension to full flexion. This would be sufficient just to reveal any change of AP condylar position of both femoral condyle simultaneously.

Fig. 1 – ADVANCE Medial Pivot prosthesis with ‘double high’ tibial insert (Wright Medical Technology, Inc.).

Both the tibiofemoral AP position and PFT were determined in true lateral flexion radiographs as follows: One line along the tibia base plate was depicted and a mid-sagittal point of the base plate was obtained by dividing the base plate length in half and then the first perpendicular line was drawn from this point. The other line parallel to the line of tibia base plate was drawn while abutting the femoral condyle and the abutting point was pinpointed and considered as tibiofemoral AP position, from which the second orthogonal line was drawn. The distance between these two orthogonal lines which are parallel was measured to determine the amount of PFT (Fig. 3A and B). All the measurements were made electrically using a built-in instrument in a digital imaging system (Infinit, Seoul, Korea). To avoid possible error caused by magnification, we used template of femoral component. We adjusted the anteroposterior length of this in true lateral radiograph in the digital imaging system until that exactly fit the known size of the template. The length of the tibial base plate in full extension might be different from that of active flexion because of tibial internal rotation during progressive flexion of knee from extension to flexion. So, in each lateral radiograph, femoral AP condylar position was indicated whether it is anterior (positive value) or posterior (negative value) to midpoint of base plate and expressed as proportion of the length between midpoint of base plate and AP condylar position to the half length of whole base plate. All the measurements were performed by two observers who didn't know the names of cases and average value was taken.

Fig. 2 – A and B. Intraoperative finding of posterior femoral translation of femoral component. A; front view, B; medial view.

2.3. Statistics

Statistical analyses were as follows: a paired t-test and Pearson correlation were performed in order to compare and associate pre- and postoperative maximum knee flexion. Correlation between postoperative maximum knee flexions and maximum PFTs was investigated with Steadman rank correlation and regression analysis. A software (dBSAT for

windows 5.0; 2010, DBSTAT Co., Seoul, Korea) was used for statistical analyses and the p values of less than 0.05 were considered significant. Post hoc analysis of power was performed with effect size of 0.3611 (using Cohen's d index of effect size)⁷, the sample size of thirty and the significance (α) level of 0.05 to ascertain any increment of postoperative maximum knee flexions compared with preoperative ones.

3. Results

Each of full flexion lateral radiographs revealed consistently posteriorly located tibiofemoral AP positions in all our cases (-0.51 ± 0.10), which means there would not be any paradoxical anterior motions of femoral components. The PFTs averaged $0.31 (\pm 0.12)$ of half length of tibial base plate and showed significant linear correlation with the maximum active knee flexions ($r = 0.56$, $p = 0.0012$) (Fig. 4).

At last follow-up, the mean Knee Society (KS) knee score and the mean function score improved significantly compared to preoperative ones (from 61.5 to 90.4 and from 57.8 to 84.7 respectively) (Table 1). The KS knee score were excellent in 15 knees (50%), good in 9 knees (30%). The mean maximum flexion of knee increased postoperatively compared to preoperative one but didn't show statistical significance ($105.5^\circ \pm 11.2^\circ$ vs. $109.3^\circ \pm 9.8^\circ$, $p = 0.051$, $\beta = 0.387$) (Table 1). Nevertheless, regression analysis showed a good linear association ($r = 0.53$, $p = 0.0027$) between the pre- and postoperative maximum flexions of knee.

The postoperative alignment of prosthesis is also shown in Table 1. There were no cases having evidence of loosening between bone-cement or cement-implant interface except for one case of instability related to medial laxity caused by trauma.

4. Discussion

Medial pivot concepts of knee kinematic have been accepted widely and medial pivot design of TKA has a few unique features as described by Blaha.¹ First, medial ball in socket feature confers optimal AP stability during knee motion while allowing some translation, posterior rolling and sliding to occur in the lateral condyle. Second, the distal and posterior

Fig. 3 – A and B. Magnitude of maximum posterior femoral translation is the amount of transition of AP condylar position from full extension (A) to full active flexion (B) radiograph. In lateral view, AP condylar position is pinpointed at one abutting point of a parallel line with base plate with femoral condyle and represented by proportion to half length of base plate.

Fig. 4 – Correlation of degrees of the maximum flexion of knee with amounts of maximum posterior femoral translation ($r = 0.56$, $p = 0.0012$).

femoral condyle has a single radius, which has the effect of optimizing the lever arm of quadriceps extensor muscle. Third, it is not necessary to resect further bone in notch area for housing the post as in PS design. Forth, it allows trochlear milling to enhance patellofemoral motion.

There have been many ongoing clinical studies reporting favorable outcomes of medial pivot TKA prosthesis.⁸⁻¹⁰ But, concerning the maximum knee flexion obtainable with Advance medial pivot prosthesis, some authors reported discouraging results.^{11,12} In our series, the mean maximum obtainable flexion of knee improved at last follow-up compared with preoperative one (from $105.5^\circ \pm 11.2$, preoperatively to $109^\circ \pm 9.8$, at last follow-up), but wasn't significantly different and seemed to be smaller than those of other reports.⁸⁻¹⁰ From the standard deviation of each, we could also found that the postoperative maximum flexions tended to be distributed within a little narrower range compared with that of preoperative maximum flexions. All these findings may be attributable to constraining effect of medial pivot TKA even if we facilitate posterior rollback by selecting double-high polyethylene insert while preserving PCL.

Moonot et al⁵ performed tibiofemoral kinematic analysis of knee flexion for one medial pivot TKA prosthesis and reported the medial condyle translated posteriorly about 2 mm at maximum flexion irrespective of weight-bearing, but lateral condyle translated posteriorly about 5 mm at maximum weight-bearing flexion and about 11 mm at maximum kneeling flexion respectively. In our study, although

incorporated mediolaterally, PFT could be reliably observed during the progressive flexion of knees and the amounts of PFTs correlated significantly with the degrees of postoperative maximum flexions of knees ($r = 0.57$, $p = 0.0009$). The probable mechanism of decreased knee flexion with lesser amount of PFT is either tibiofemoral impingement resulting in decreased clearance or the tightness of extensor mechanism with decreased quadriceps lever arm as the femoral component translates anteriorly instead of posteriorly with progressive flexion of knee.¹³ This tibiofemoral impingement may mitigate against the flexion of knee by a similar mechanism where inadequate posterior femoral offset may limit the flexion of knee by impingement.¹⁴ The tibiofemoral AP positions were also located consistently posterior to the middle of base plate in all our cases. This means there may not be any paradoxical anterior motions of femoral components throughout the range of motion and this may be attributable to elevated anterior lip of tibial insert and enhanced conformity between the femoral and tibia component of this medial rotation TKA prosthesis.

There are many contributing factors in obtaining optimal flexion after TKA including patient factors, surgical technique, complication, rehabilitation, prosthetic design and TKA kinematics.¹³ In addition to PFT as one kinematic factor, other kinematic factors are also important in improving the knee flexion after medial pivot TKA. First, internal tibial rotation combined with progressive flexion of knee might be also necessary for the flexion of knee but couldn't be measured fluoroscopically in this study. Second, it should be determined how much lateral laxity is optimal for lateral femoral condyle to translate adequately posteriorly in medial pivot TKA, while according to Okazaki et al¹⁵, the mean 4.8° in varus stress was revealed in normal knee of flexion state, which correspond to 5 mm opening of lateral compartment if the tibial plateau is 6 cm in width.

Quadriceps weakness is often present in osteoarthritic limb and worsens after TKA.¹⁶ There are various factors related to quadriceps function such as implant design, surgical factor, patellofemoral articulation and rehabilitation etc. Of these, the implant related factor favoring quadriceps function was reported to have single radius in flexion-extension and show progressive posterior translation of the tibiofemoral contact area.¹⁶ Mahoney et al¹⁷ reported that more patients with single radius implants can rise from a sitting position at 6 weeks postoperatively than can patients with multiradius implant. Wang et al¹⁸ also confirm this finding in a study in which a single radius implant took a significantly less time to rise from a sitting to a standing position compared with those with a multiradius implant. This may be attributable to the more posteriorly located center of the sagittal radius in the flexion of knee in case of single radius design.¹⁹ The femoral component of Advance has also constant sagittal radius of curvature extending from full extension to 90° flexion and its DH design has the feature of flexion path structure facilitating PFT. These two points may be helpful to increase the quadriceps moment arm and should lead to lesser quadriceps force required to extend the leg and lesser patellofemoral compressive forces and should aid in implant survival.¹⁹ Our cases revealed that the tibiofemoral contact points were consistently posteriorly located along the tibia base plate even at higher flexion angle, which was also reported by Barnes et al⁴.

Table 1 – Pre- and postoperative clinical and radiological results.

Variables	Preoperative	Postoperative	p-value
Knee society knee score	61.5 ± 7.9	90.4 ± 8.8	<0.001
Knee society function score	57.8 ± 8.3	84.8 ± 7.4	<0.001
Maximum flexion angle	105.5 ± 11.2	109.3 ± 9.8	0.051
Tibiofemoral angle	9.2 ± 6.5 (varus)	5.3 ± 2.7 (valgus)	<0.001
Alignment of implant			
α	—	95.6 ± 3.7	—
β	—	89.7 ± 2.2	—
γ	—	2.5 ± 3.6	—
δ	—	81.6 ± 2.8	—

Advance medial rotation knee has bone-conserving property in that it is not necessary to cut a box of bone from femoral notch for accommodation of the polyethylene post as in TKA prosthesis of PCL substituting type. It has anteriorly elevated polyethylene lip acting like a post to prevent posterior sagging. Cho et al¹⁰ thought this characteristic may be advantageous in case of revision TKA and this type of TKA prosthesis may be applicable to younger patients. Advance medial rotation knee also have patella-friendly femoral trochlear by allowing trochlear milling, which was thought to enhance patellofemoral mechanism but we couldn't find any evidence for the advantages of this feature because we didn't have any control group and patellofemoral tracking is influenced multifactorially. As a concern about Advance medial rotation knee, early component loosening may be a problem as increased shearing caused by high congruency and edge loading in high flexion may have negative effect on bone-implant interface. But there were no cases showing either component migration or radiolucent line in our thirty case series of minimum 2-year follow-up.

There were a few limitations in our study. First, the follow-up period was short and the number of consecutive cohorts appeared to be small during the selection period of one year even though this is a prospective longitudinal study. Second, there could be a referral bias in which the selected patients are limited to our community general hospital. For further study, we are planning to follow-up upon large cohorts including cases from other hospitals including tertiary care hospital for longer time. Third, our inclusion criteria were age between 60 and 75 years and primary degenerative joint disease of knee graded as Kellgren Lawrence grade III or higher. The criterion of age need to be stratified in a few subgroups and it is wondered whether there would be same results if we include other inflammatory joint diseases. Forth, our study was based upon 2-D fluoroscopic lateral image in which it is impossible either to measure the PFT of each femoral condyle separately or to evaluate any rotational movement in addition to AP motion. For this purpose, we need to perform in vivo 3-D kinematic analysis in the future.

5. Conclusions

In medial rotation TKA of PCL retaining type, clinical outcome was satisfactory. The maximum obtainable flexions didn't show significant improvement at two- to three-year follow-up compared with preoperative ones. Nonetheless, posterior femoral translations were consistently observed during progressive flexions of knee, which was considered to be an important kinematic factor in increasing the level of knee flexion of medial rotation TKA in longer follow-ups by providing greater posterior clearance and reduced femoro-tibial impingement.

Conflicts of interest

All authors have none to declare.

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