

# Comparison of Clinical Outcomes Between Total Knee Arthroplasties Using Medial-Pivot and Posterior-Stabilized Prosthesis: Minimum 8-year Follow-up Results in Chinese population

**Zheng-yu Gao**

The Affiliated Hospital of Qingdao University

**Cui-cui Guo**

The Affiliated Hospital of Qingdao University

**Zi-an Zhang**

The Affiliated Hospital of Qingdao University

**Guang-qian Shang**

The Affiliated Hospital of Qingdao University

**Wei-ning Yan**

The Affiliated Hospital of Qingdao University

**Shuai Xiang**

The Affiliated Hospital of Qingdao University

**Hai-ning Zhang**

The Affiliated Hospital of Qingdao University

**Ying-zhen Wang**

The Affiliated Hospital of Qingdao University

**Hao Xu** (✉ [18661806627@163.com](mailto:18661806627@163.com))

The Affiliated Hospital of Qingdao University

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## Research article

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# Abstract

**Objective** To compare the clinical outcomes of Medial-pivot and Posterior-stablized total knee arthroplasty during 8 years follow-up.

**Methods** 109 patients with osteoarthritis who underwent primary total knee arthroplasty were conducted and divided into two groups according to the choice of prosthesis,49 in the Medial-pivot(MP) group and 60 in the Postirior-stabilized(PS) group. There were no statistical differences in age,gender,BMI,operative side and operation time between the two groups ( $P>0.05$ ). The same protocol of perioperative treatment was adopted in both groups. Comparison of clinical outcome and survival rates were acquired through minimum 8 years follow-up.

**Results** The prosthesis survival rate and the excellent and good rate of MP group were 93.9% and 88.9% during average 8.3 years follow-up period, versus the prosthesis survival rate and the excellent or good rate of PS group were 93.3% and 86.7% during average 8.4 years follow-up period. There were no statistical diferences in survival rate,excellent and good rate and radiolucency of weight-bearing areas between the two groups ( $P >0.05$ ). There were no statistical differences in range of motion,KSS score and WOMAC index between the two groups preoperatively ( $P>0.05$ ). The range of motion at all follow-up time points and KSS score at 6 months postoperatively of PS group were superior than those of MP group ( $P <0.05$ ), while the WOMAC index at 8 years postoperatively and Kujala scores at 1 year and 8 years postoperatively of PS group were better than those of MP group( $P <0.05$ ).

**Conclusion** Either medial-pivot or post-stabilized total knee arthroplasty could obtain excellent or good mid-term clinical result. Although with less range of motion, the patients using MP prosthesis could obtain better results in bone loss, performance of the patellofemoral joint and mid-term satisfaction. However, the use of MP prosthesis required more professional and precise technology and it should be cautious when using for knees with severe valgus deformation.

## Background

Total knee arthroplasty has proven to be a reliable and long-lasting treatment for knee osteoarthritis[1]. The traditional posterior-stabilized knee prosthesis design provides stability of the knee joint, with a 15-year prosthetic survival rate of 95% and satisfactory clinical effects[2]. However, many scholars still believe that the design of posterior-stabilized(PS) knee prostheses does not fully simulate the movement of biological knee joints, especially the internal and external rotation of the femur and locking motion of the medial compartment during flexion and extension of normal knee joints. These mechanical changes may result in local stress concentrations leading to local wear of the prosthesis[3–5]. This wear may be one of the causes of aseptic loosening and revision surgery. In addition to common patellofemoral joint problems after traditional posterior-stabilized knee arthroplasty, patients sometimes have persistent patellofemoral joint pain. These issues are potential risk factors that lead to the inability to obtain a long-lasting and stable knee and ultimately lead to a revision[6, 7]. Based on these theoretical foundations, the

medial-pivot (MP) prosthesis designed by Wright, an American company, uses the medial femoral and tibial chamber of the knee joint as the rotating axis, simulates natural movement of the knee more authentically, and maintains complete stability of the knee joint on all surfaces according to the anatomical design. Theoretically, the MP prosthesis has a more suitable patella track and reduces the amount of contact stress and polyethylene wear, and it may achieve better surgical outcomes and a longer service life[8]. Many scholars have reported the medium- and long-term effects of knee replacement with medial-pivot prostheses[9–11]. As both China's aging population and the age of the working population continues to increase, the number of elderly patients receiving artificial knee replacement will further increase in the future. Better prosthesis stability, higher postoperative satisfaction and longer service life will be the decisive factors for all joint replacement doctors and patients in selecting a prosthesis. In order to verify the clinical effects of the new medial-pivot prosthesis compared with the traditional medial-pivot prosthesis, the authors selected 109 patients who underwent knee replacement surgery, were followed up for more than 8 years by the same primary surgeon team, and received either a MP or a PS knee prosthesis; the mid-term clinical effects of the two types of prostheses were compared and analyzed.

## Methods

### 1 Objectives

A total of 109 patients with knee osteoarthritis admitted between January 2010 and July 2011 were selected for primary unilateral knee arthroplasty. According to the prosthesis selection, they were randomly divided into two groups: one group received the ADVANCE Medial-Pivot knee by Wright, and the other group received the NexGen LPS-Flex Fixed Bearing knee by Zimmer (Fig. 1). There were 49 patients in the MP group, including 15 males and 34 females, with an average age of 64.5 years (53–73 years) and an average weight of 67.7 kg (51–98 kg). The angle of varus deformity of the knee joint was  $14.3^\circ$  (0–20°), and the angle of flexion deformity was  $13.6^\circ$  (0–28°). There were 60 patients in the PS group, including 17 males and 43 females; the average age was 66.2 years (58–77 years), the average body weight was 65.9 kg (56–85 kg), the average angle of varus knee deformity was 15.5 (0–20), and the average angle of flexion deformity was 15.8 (0–30). No knee valgus deformity, prior knee surgery, or knee instability were found in the two groups. There were no statistically significant differences in age, body mass index, sex ratio, operative side ratio and average operative time between the two groups ( $P > 0.05$ , Table 1). Patients with significant knee movement limitations due to other non-knee replacement reasons during the follow-ups were excluded.

Table 1  
General data of patients ( $x \pm s$ )

parameter	MP group	PS group
Number of patients	49	62
Age (years)	64.5 ± 10.6	66.1 ± 9.8
Gender (male/female)	15/34	18/44
BMI (kg/m <sup>2</sup> )	27.88 ± 4.26	27.12 ± 5.35
Operative side (left/right)	20/29	24/38
Operation time (min)	81.7 ± 5.5	82.3 ± 5.2

## 2. Methods

All patients underwent surgery performed by the same surgeon with the same perioperative management and postoperative rehabilitation program.

### 2.1 Preoperative preparation

(1) Preoperative education for the patients involved informing them of the necessity and safety of surgery, providing a full conceptual explanation, and teaching the patients how to perform functional exercises. (2) The prophylactic medication included celecoxib 200 mg taken orally twice a day for 3 days before surgery and cephalosporin generation antibiotics that were administered intravenously to prevent infection 30 min before operation. (3) With the knee joint anteroposterior and lateral radiographs, patella axial radiographs and full-length radiographs were taken to measure the femoral tibia angle of the knee joint and observe the lucency area around the prosthesis.

### 2.2 Operation

The operation was performed under epidural anesthesia, and the operation was performed with a balloon tourniquet at the suture incision, the anterior median knee incision, the medial patella approach, and the routine osteotomy and soft tissue release. In all cases, only patella resurfacing not patella replacement was performed, and lateral release was not performed in any case. Drainage tubes were placed intraoperatively, and elastic bandages were applied to the lower limbs.

### 2.3 Postoperative management

After the operation, the drainage tube was removed after 24–48 h, and an ice pack was applied. On the second day after the surgery, the continuous passive activator (CPM) functional exercise usually started with 40° and increased by 10–20° each day to reach more than 90° within a week. On the second day after the operation, the patient was encouraged to stand at the bedside with the help of medical staff, then began to walk and exercise. After surgery, cephalosporin generation antibiotics were used for 48 hours to

prevent perioperative infection, and one dose of low molecular weight heparin 5000 IU was used within 24 hours after surgery for the prevention of deep vein thrombosis (DVT).

## 2.4 Postoperative follow-up

All patients were followed up regularly; they were followed up at 6 weeks, 3 months, 6 months, 1 year, and once a year thereafter. The patients' degree of mobility, pain and satisfaction were recorded, the knee joint was examined by A-P and lateral X-ray examination, and the knee joint angle was measured. Knee function and patient satisfaction of the two groups were evaluated and compared before the operation and 6 weeks, 3 months, 1 year, 3 years and 8 years after the operation.

## 2.5 Observation indexes

(1) The patella inclination angle is defined as the angle between the anterior intercondylar line and the transverse axis of the patella (Fig. 2). The transverse axis of the patella is the line between the medial and lateral angles of the patella. Measuring the transverse axis by this method is not influenced by patellar morphology and may be helpful for the clinical evaluation of tilt angle. The medial and lateral angles of the patella are determined by referring to the axial X-ray of the patella. The angle of patella inclination is defined as positive when the transverse axis of the patella is tilted outward relative to the anterior intercondylar line.

(2) Patella displacement is defined as the distance between the intercondylar sulcus and the middle ridge of patella (Fig. 3). The intercondylar sulcus is defined as the deepest point of the femoral pulley, which, on the X line, is the lowest point of the pulley relative to the anterior intercondylar line. The lowest point of the intercondylar sulcus was determined by moving the digital drawing of the front of the intercondylar sulcus to the lowest point of the intercondylar area to reduce variation among observers. The middle ridge of the patella is also defined as the lowest point of the patella relative to the transverse axis of the patella. The middle ridge of the patella was determined by digitally moving the horizontal axis of the patella down to the lowest part of the patella. When the middle ridge of the patella was lateral to the intercondylar groove, we set the patella displacement as positive, and when the point was medial to the intercondylar groove, we defined it as negative.

(3) Range of motion (ROM) was measured.

(4) The KSS (Knee Society Score) knee score and functional score were used to evaluate knee function.

(5) The WOMAC (the Western Ontario and McMaster Universities Osteoarthritis Index) scoring system can evaluate surgical effects and patient satisfaction.

(6) The Kujala scoring system was used to evaluate preoperative and postoperative patellofemoral joint function.

## 2.6 Statistical analysis

All data were expressed as the mean plus or minus ( $\pm$ ) the standard deviation ( $x \pm s$ ), and statistical analysis was performed using SPSS20.0 statistical software. An independent samples t test was used for continuous measurement data, and a  $\chi^2$  test was used for categorical data;  $P < 0.05$  indicated a statistically significant difference.

## Results

The MP group was followed up for an average of 8.3 years. Among this group, there were 3 cases of revision, 1 case of infection and 2 cases of replacement of the polyethylene insert due to instability of the knee joint. The survival rate of the prostheses was 93.9% (46/49), and the excellent and good rate was 89.8% (44/49). In the fixed platform group, the average follow-up period was 8.4 years. In this group, there were 4 cases of revision, 1 case of infection, 2 cases of refractory knee pain caused by aseptic loosening, and 1 case of periprosthetic fracture; the survival rate of the prostheses was 93.3% (56/60), and the excellent and good rate was 86.7% (52/60). There were no significant differences between the two groups in the survival rate or excellent and good rate ( $P > 0.05$ ). Another patient in the MP group complained of an unstable knee joint when descending stairs, but the knee did not affect his or her ability to ascend stairs or walk on level roads. Follow-ups were continued to observe changes in the condition. Postoperative X-ray measurements showed that there was no significant difference in the femoral and tibial comparisons between the two groups before and after operation. At the last follow-up X-ray examination, there were 3 patients in the PS group and 2 patients in the MP group. There was obvious light transmission ( $> 2$  mm) in the load-bearing area of the medial tibial plateau but no specific clinical symptoms. In terms of knee joint function and satisfaction, there was no significant difference in knee joint mobility, the KSS, the WOMAC score or the Kujala score between the two groups before the operation. The knee joint activity in the PS group was better than that in the MP group at 6 weeks, 1 year and 8 years after the operation. The difference was statistically significant. The KSS score of the PS group at 6 weeks after surgery (including the total score of the knee score + the functional score) was better than that of the MP group, but there was no difference in the KSS score at 1 year and 8 years after surgery. In terms of the WOMAC score, there was no statistically significant difference between the two groups at 6 weeks and 1 year after surgery, but the MP group score was better than the PS group score at 8 years after surgery, and the difference was statistically significant. For the Kujala score for the patella function evaluation, there was no difference between the two groups at 6 weeks after surgery, but the Kujala score of the MP group at 1 year and 8 years after surgery were better than those of the PS group, and the difference was statistically significant. There was no significant difference in patellar tilt angle and patellar displacement between the two groups before and after operation (Tables 2, 3, Figs. 4–6).

Table 2  
Comparison of clinical evaluation results between MP group and PS  
group ( $x \pm s$ )

Parameter	MP group	PS group	t	p
Range of motion (ROM)				
Preoperation	86.1 ± 10.3	83.5 ± 10.5	1.958	0.077
6 weeks	105.3 ± 10.8	112.2 ± 9.5	3.594	< 0.001
1 year	115.7 ± 10.6	123.1 ± 11.1	3.558	< 0.001
8 years	118.5 ± 10.5	124.6 ± 10.2	3.095	0.002
KSS scores (knee score + functional score)				
Preoperation	74.8 ± 5.5	72.6 ± 6.7	1.852	0.083
6 weeks	110.9 ± 9.2	118.6 ± 8.7	4.527	< 0.01
1 year	168.3 ± 9.2	171.1 ± 8.8	1.636	0.105
5 years	172.7 ± 9.6	174.2 ± 8.9	0.855	0.395
WOMAC index				
Preoperation	131.3 ± 17.2	135.9 ± 18.1	1.486	0.158
6 weeks	68.7 ± 11.4	71.5 ± 10.6	1.341	0.183
1 year	26.6 ± 6.4	29.1 ± 7.8	1.806	0.074
8 years after	22.5 ± 4.6	25.8 ± 5.2	2.430	0.017
Kujala score				
Preoperation	47.6 ± 7.1	49.7 ± 7.8	1.102	0.276
6 weeks	75.8 ± 9.1	76.7 ± 8.6	0.535	0.594
1 year	81.5 ± 8.7	79.9 ± 7.7	2.320	0.022
8 years after	82.8 ± 8.6	80.3 ± 8.0	2.222	0.028

Table 3  
Comparison of patella inclination angle and patella displacement before and after surgery.

	MP group	PS group	t	p
Angle of patella inclination (°)				
Preoperation	6.08 ± 2.58	5.79 ± 2.83	0.53	0.594
1 year	2.67 ± 1.68	2.84 ± 1.92	0.47	0.643
Patella displacement (mm)				
Preoperation	1.63 ± 3.37	1.66 ± 3.05	0.04	0.962
1 year	0.63 ± 1.72	1.15 ± 1.94	1.40	0.165

## Discussion

After more than 30 years of clinical practice, artificial knee replacement has become a successful surgery, and it can provide patients with a painless and functional knee[12]. Moreover, with the continuous improvement of knee prostheses and surgical techniques, the clinical effect has improved[13].

The medial-pivot knee prosthesis is a new type of knee prosthesis, which is different from the traditional posterior-stabilized prosthesis[14]. Its main purpose is to simulate the physiological movement of a normal human knee joint to the greatest extent possible. The medial compartment is used as the axis to form a spherical fossa joint and maintain stability of the knee joint during movement, while the lateral compartment has a rotation range of mobility of 10–15° as the knee joint flexion and extension[15]. The main advantage of this design is that it replaces the traditional posterior-stabilized cam roll-back column design[16], reducing the amount of bone to be cut during surgery and the point-to-point contact stress during joint movement, thereby reducing the risk of polyethylene wear and increasing the service life of the prosthesis.

The authors selected 109 patients with osteoarthritis and divided them into two groups for comparative analysis. The preoperative sex ratio, age, body mass index, operation time, operative side ratio and knee joint deformity characteristics were basically the same in the two groups, and all operations were performed by the same surgeon in the author's medical group. Follow-ups showed that the knee range of motion (ROM) of the MP group was lower than that of the PS group at all postoperative follow-up time points, and the KSS score of the MP group at 6 weeks after surgery was also lower than that of the PS group, but there was no difference in the KSS score between the two groups at 1 and 8 years after surgery. First, the Zimmer LPS prosthesis selected for the control group was a high-flexion total knee prosthesis. By raising the front and rear lips of the polyethylene pad and the posterior rollback device, the knee range of motion was allowed to reach a maximum of 150aximum of motion was allowed to reach knee prosthesis. By raising the front and rear lips of the polyethylene pad and the pos failure and is

associated with a risk of knee dislocation. A later follow-up confirmed the existence of such concerns. Three patients in the MP group had postoperative instability of the knee joint in a flexion position, especially when the knee was partially flexed for descending stairs. Two of these patients underwent surgical relief by having the thicker polyethylene pads replaced, and the remaining patient did not undergo revision surgery because the issue had no significant impact on his or her quality of life. Regarding this concern, MP prostheses in artificial joint replacement surgery tend to "tighten rather than loosen" when performing soft tissue release in the knee bend position, which affects knee mobility to some extent. Therefore, some scholars believe that the rotation alignment requirement of the tibial bracket for a knee prosthesis with an inner-axis design is more tolerant than that of the posterior stabilized type of prosthesis [17], which is incorrect. In contrast, MP TKA requires more precise techniques than PS TKA in the soft tissue balance because an imbalance brings higher risk of instability and dislocation of polyethylene bearing after operation in MP TKA. Therefore, the placement of the prosthesis, the balance of space for flexion and extension, and the degree of soft tissue release all require delicate manipulation when performing the movable platform exercises. To solve this problem, the second generation EVOLUTION medial-pivot knee prosthesis launched by Wright has made considerable improvements in terms of increasing knee flexion and stability[18]. However, the long-term clinical effect of this new prosthesis needs to be further confirmed by follow-ups.

However, good knee mobility does not necessarily lead to better satisfaction. Studies by Miner have shown no difference in satisfaction between patients with a range of motion larger than 100° and no difference in satisfaction between patients with a range of motion is problem, the second generation mobility to some extent[19]. and prothe MP group was lower than that of the PS group at 6 weeks after surgery, there was no difference between the two groups at 1 year after surgery, and there was no difference between the two groups at 8 years after surgery. Even the WOMAC score was better in MP group at 8 years after operation ( $P > 0.05$ ).

Patients with MP prostheses were more satisfied, again confirming that activity was not completely consistent with satisfaction. The Kujala scores of patellofemoral joint function for the MP group at 1 year and 8 years after surgery were higher than those of the PS group because of the medial-pivot prosthetic design concept; during knee flexion, the lateral joint compartment relative to the medial compartment has a certain degree of rotation, thus increasing the permissibility of the patella block during knee flexion and extension, and better patellofemoral trajectories can often be obtained. Patellofemoral joint function is an important factor that affects satisfaction after knee arthroplasty. Of course, the authors also believe that regardless of the type of knee prosthesis that is adopted, the surgical technique is the key to ensuring a favorable range of motion and patient satisfaction. The two most important parts are making an accurate bone cut and a good soft tissue balance in order to ensure a correct lower limb line of force and establish a symmetrical and balanced gap for knee extension and flexion.

The long-term survival rate of prostheses is always the gold standard to measure the success or failure of knee replacement surgery. Previous studies suggested that MP prostheses can provide better articulating joints while reducing the contact stress load on the fixed surface, which should reduce the risk for

loosening [20, 21]. However, an increasing number of authors have confirmed that the wear of this type of joint is affected by many mechanical and biological factors, so the long-term life of the prosthesis cannot be measured by a single factor[22]. In this study, the 8-year follow-up results of patients with the MP prosthesis and PS prosthesis demonstrated that the 5-year service life of an MP prosthesis and a PS prosthesis was higher than 90%, that the excellent and good rate was higher than 85%, and that there was no significant difference between the two groups. Regarding the early manifestations of aseptic loosening, 3 patients in one group and 2 patients in the other group showed small light transmission zones in the loading area, but no clinical symptoms were observed, and the difference was not statistically significant. Additional follow-up observations were required for assessing the progression. An important disadvantage of this study is the high rate of failure in the long-term follow-up. During the same period, 208 patients undergoing unilateral knee arthroplasty with MP and PS prostheses were enrolled in the author's medical group. However, only 109 patients completed the 8-year follow-up according to our requirements, including patients with failed cases, and the rate of loss for the follow-ups was as high as 47.6%. In general, the satisfaction and survival rate of patients with incomplete follow-ups were higher than those of patients with complete follow-ups, so the overall survival rate and good rate of the prostheses may be higher than those in the results of this study.

Another important concern in the selection of MP prostheses is the strict criteria for case selection. Due to social traditions and economic factors, Chinese patients often have severe joint deformities requiring joint replacement surgery[23]. For patients with severe varus or flexion contractures, the long-term effect and satisfaction of MP prostheses are not worse than those of PS prostheses[24], and MP prostheses have more advantages at simple operation, more bone retention and better patellar tracking. However, because the purpose of the MP prosthesis design is to use the medial compartment as the stabilization mechanism and the center of rotation in flexion and extension, MP prostheses should be carefully applied to patients with genu valgus, especially those with severe genu valgus rheumatoid arthritis. The medial structure of the knee joint in these patients is often very relaxed, and instability of the medial structure of the knee joint is often progressively aggravated after operation. Currently, the application of MP prostheses is associated with a high risk for medial instability or dislocation after operation.

## Conclusions

The medial-pivot knee prosthesis is a new type of artificial knee prosthesis that more closely mimics a normal knee. Compared with the traditional posterior-stabilized prosthesis, the MP prosthesis can also effectively correct knee deformities, relieve knee pain, improve knee function, and provide a medium-term satisfactory artificial knee joint. Evaluation of the long-term service life of the MP prosthesis and patient satisfaction with the prosthesis need additional follow-up studies. Although the overall range of motion after operation is lower with the MP prosthesis than with the PS prosthesis, the amount of osteotomy required is lower, the patellofemoral joint function after operation is better, and the satisfaction at a mid-term follow-up is better with the MP prosthesis than with the PS prosthesis. In addition, MP prosthetic knee arthroplasty requires highly experienced surgical techniques, especially soft tissue balance techniques, and caution should be exercised in the selection of valgus knee cases.

# Abbreviations

MP: Medial-pivot; PS: Posterior stabilized; TKA: Total knee arthroplasty; ROM: Range of motion; KSS: Knee Society Score; WOMAC: the Western Ontario and McMaster Universities Osteoarthritis Index

# Declarations

## Ethics approval and consent to participate

Ethical approval was obtained from Ethical Committee of The Affiliated Hospital of Qingdao University in China (Project Number: QDYNA20100109).

## Consent for publication

Not applicable.

## Availability of data and material

Not applicable.

## Competing interests

The authors declare that they have no competing interests.

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## Authors' contributions

Hao Xu had the original idea for this study and secured funding. Zheng-yu Gao and Guang-qian Shang collected the data and did most of the writing of the current manuscript. Cui-cui Guo are recruiting patients for the study. Zi-an Zhang and Ying-zhen Wang are treating the patients in this study. Wei-ning Yan conducted the analysis and wrote the proposed statistical approach. Hai-ning Zhang contributed with scientific and clinical expertise. All authors were involved in the study design and protocol development. All authors read and approved the final manuscript.

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## Figures



(a)



(b)

Figure 1

a: Wright's Advance MP knee system; b: Zimmer's LPS-Nexgen knee system

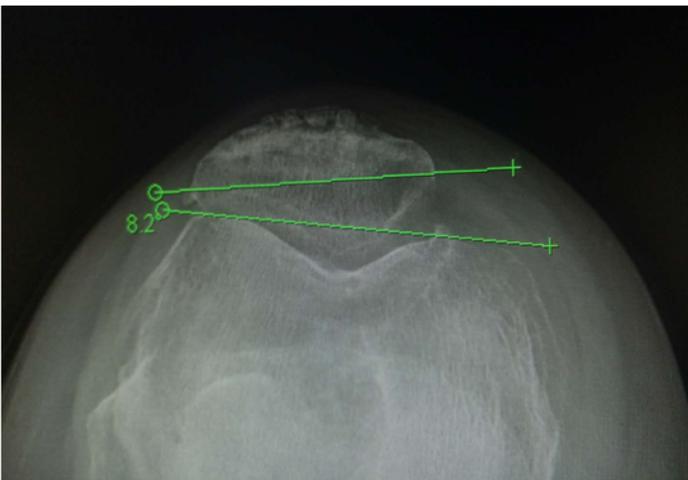
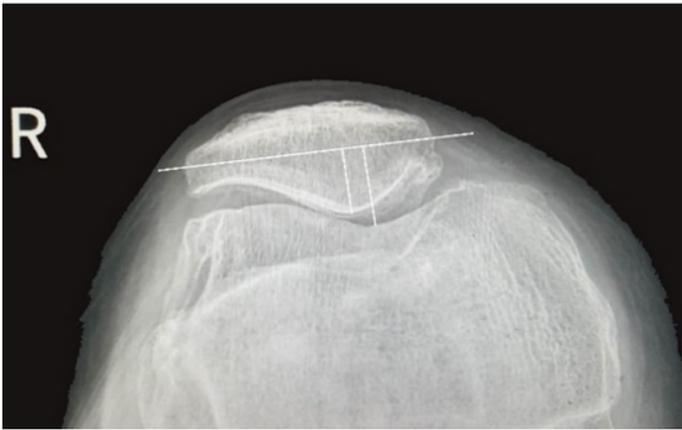


Figure 2

Patella tilt angle is the angle formed by the anterior intercondylar line and the transverse axis of patella, which is automatically measured by image software. Obtain, as shown in the figure, the patella is tilted

laterally in a positive angle.



**Figure 3**

The displacement of patella is the distance between the condylar groove and the mid-patellar ridge. The lowest point of the condylar groove and the mid-patellar ridge should be located first. The vertical line between the two points and the transverse axis of the patella should be made. The distance between the two perpendicular lines is the displacement of the patella. Negative value, as shown in the figure, the left patellar displacement is positive, and the right patellar displacement is negative.