Original Article

Comparative Study of Mobile- and Fixed-Bearing Unicompartmental Knee Arthroplasty in Medial Osteoarthritis: A Prospective Randomized Study of Bone Preservation and Early Clinical Outcomes

Chumroonkiet Leelasestaporn MD[1], Udom Tantipanpipat MD[2]

[1] Department of Orthopaedic Surgery, Bhumibol Adulyadej Hospital, Bangkok, Thailand
[2] Department of Orthopaedic Surgery, Panyanantapikkuchonprathan Medical Center, Srinakarinwirot University, Bangkok, Thailand

Background: Medial osteoarthritis performed with fixed-bearing UKA and with mobile-bearing UKA have both had excellent survivorship reports. However, there have been no clinical studies of outcomes of the two systems or studies of bone preservation.

Objective: The objectives of this study were to compare intraoperative bone preservation and early clinical and radiological outcomes between fixed-bearing and mobile-bearing unicompartmental knee arthroplasty in medial osteoarthritis.

Materials and Methods: Between July 2012 and June 2013, 40 consecutive, unicompartmental knee arthroplasties were performed on 40 patients. The authors prospectively randomized those patients into two groups: twenty fixed-bearing unicompartmental knee arthroplasties [UKA] were conducted in group 1 and 20 mobile-bearing unicompartmental knee arthroplasties were conducted in group 2. Intraoperative data recorded included the amount of bone resection, operative time, blood loss, wound length, length of stay, and post-operative knee alignment, the latter assessed using the Kennedy and White classification system. Knee Society scores and Functional scores were recorded postoperatively at one month, three months, six months, one year and two years for clinical evaluation.

Results: Group 1 (fixed-bearing) had significantly more bone weight resection than group 2 (mobile-bearing) at 22.0 mg versus 15.90 mg ($p = 0.002$). Differences in early clinical outcomes between the two groups were not statistically significant. Postoperative mechanical axis alignment, based on radiographic assessment with the Kennedy and White classification, showed 75% of the mobile-bearing UKA patients in Zone C and 70% of the fixed-bearing UKA patients in zone II. Three patients (7.5%) had postoperative complications: one in the fixed-bearing group had a medial tibial plateau fracture and one in the mobile-bearing group had a superficial wound infection, both of which were successfully treated conservatively. The remaining patient, had a bearing dislocation treated with a revision with thicker polyethylene.

Conclusion: This study demonstrated that mobile-bearing UKA achieves significantly better bone preservation due to lower bone loss when compared with fixed-bearing UKA. However, fixed-bearing UKA requires less surgical time and involves fewer safety procedures. Both fixed-bearing UKA and mobile-bearing UKA patients had excellent early clinical outcomes.

Keywords: Medial compartment knee disease, Unicompartmental knee arthroplasty, Fixed-bearing, Mobile-bearing, UKA

J Med Assoc Thai 2018; 101 [Suppl. 3]: S101-S107
Full text. e-Journal: http://www.jmatonline.com

Correspondence to:
Leelasestaporn C, Department of Orthopaedics, Bhumipol Adulyadej General Hospital, 171 Phahonyothin Road, Saimai, Bangkok 10220, Thailand.
Phone: +66-2-5347165
E-mail: chumroonkiet_l@yahoo.com

How to cite this article: Leelasestaporn C, Tantipanpipat U. Comparative Study of Mobile- and Fixed-Bearing Unicompartmental Knee Arthroplasty in Medial Osteoarthritis: A Prospective Randomized Study of Bone Preservation and Early Clinical Outcomes. J Med Assoc Thai 2018;101;Suppl.3: S101-S107.

Unicompartmental knee arthroplasty has been recommended as an effective treatment for medial compartment osteoarthritis. Historically, the first available UKA were cemented, fixed-bearing all-polyethylene UKA[1]. In 1986, Goodfellow and O'Connor[2] described a mobile-bearing metal-backed UKA designed to improve wear characteristics. Since then, both designs have had excellent results and survivorship. Berger et al[3] retrospectively evaluated 62 consecutive fixed-bearing UKA and reported 95.7% survivorship at up to a 13-year follow-up. Other studies[4,5] have confirmed those findings, reporting 94% survivorship at a 10-year follow-up. On the other hand, mobile-bearing UKA has technical challenges in ligament balancing with a potential risk of bearing dislocation, although numerous studies have reported excellent long-term survivorship with that method. Murray et al[6] reported 98% survivorship at 10-year follow-up. Svard and Price[7] retrospectively evaluated 124 mobile-bearing UKAs with a cumulative survivorship of 95%; other studies have reported average survivorship between 85%[8] and 90%[9]. Some comparison studies between fixed-bearing UKA and mobile-bearing UKA designs, however, have had different clinical outcomes. Li et al[10] found that mobile-bearing UKA have better kinematics and a lower rate of lucencies, but no better clinical function or survivorship. Gleeson et al[11] found that fixed-bearing (St-Georg sled) achieved better pain relief, but that functional results were similar. In contrast, Confalonieri et al[12] found no statistical differences in outcomes. In summary, there has been no proven advantage of one bearing over the other and no consensus about which is better. In particular, there have been no reports comparing bone preservation between the two UKA methods. Thus, whether a fixed- or a mobile-bearing UKA should be used is still controversial. To fill that gap, this study was designed to compare fixed-bearing and mobile-bearing UKA, specifically to evaluate differences in bone preservation as well as secondary clinical outcomes. The authors' hypotheses were that mobile-bearing UKA allows greater bone preservation, provides better clinical outcomes, and generates a more neutral mechanical axis based on post-operative x-ray analysis, than fixed-bearing UKA.

Materials and Methods

With approval from the local ethics committee, candidates for unicompartmental knee arthroplasty were invited to participate in the trial. Between July 2012 and June 2013, 40 knees in 40 patients were treated with medial unicompartmental knee arthroplasty conducted by a single senior surgeon using one of two prosthesis designs. The first was a mobile-bearing tibial implant, an Oxford Partial Knee (Biomet, Warsaw, IN). The second was a fixed-bearing tibial implant with a curve on flat articulation, the Sigma® High Performance Partial Knee unicompartmental knee implant (DePuy Johnson & Johnson Company, Warsaw, IN).

The indications for patients to undergo unicompartmental knee arthroplasty were based on the recommendations of Kozinn and Scott[13]. Patients were candidates for this study if they had medial knee pain but no anterior knee pain, body weight less than 180 lbs (82 kg), intact ACL, PCL and collateral ligaments, varus deformity of less than 10° passively correctable by applying valgus force, flexion arch of more than 90°, and flexion contracture of less than 10°. Patients were accepted for the study even if preoperative standing anteroposterior and lateral radiographs confirmed an Ahlback classification of grade II or III osteoarthritis in the knee[14]. Patients were excluded if they suffered from an inflammatory joint disease such as rheumatoid arthritis, gouty arthritis, chondrocalcinosis, traumatic knee or a prior high tibial osteotomy around the knee. Age was not an exclusion criterion. The final decision to carry out unicompartmental knee arthroplasty was made intraoperatively after assessing ACL competency and the full thickness of cartilage in the lateral compartment. The condition of patella femoral articulation was classified according to the Outerbridge[15] system. Classification greater than grade III was an exclusion criterion.

Prosthesis

The mobile-bearing knee prosthesis used in this study was an Oxford partial knee replacement that consists of a cobalt-chrome [CoCr] femoral component with a spherical articular surface and single radius of curvature. The bearings are made from direct compression molded ultra-high molecular weight polyethylene, sterilized in inert argon gas. The radius of curvature of the bearing matches that of the femoral component for fully congruous contact with the femoral component and a mobile polyethylene tibial component which glides on a flat cobalt-chrome [CoCr] tibial component. The fixed-bearing prosthesis was the Sigma High Performance Partial Knee unicompartmental knee prosthesis consisting of a cobalt-chrome [CoCr] femoral component with two pegs to enhance component fixation. The articulation surface of the polyethylene is flat and is fixed to the cobalt-chrome [CoCr] alloy tibial component.

Surgical technique

The operations were performed by a single senior surgeon using a minimally invasive surgery [MIS] technique with both groups of patients. After the arthrotomy, the anterior cruciate ligament [ACL] was inspected and tested for competency by clamping, followed by a check of the lateral compartment of the femoral condyle as well as patellofemoral joint articulation to determine whether there was any erosion or fibrillation. The surgical goal with both groups was surface arthroplasty without any ligament release or overcorrection of medial soft tissue. The tibial bone resection was performed using an extramedullary guide following the patient's natural slope for both types of implants. An intramedullary alignment guide was used for bone resection of the distal femur. This was carried out in the Oxford group using a milling technique in contrast to the extramedullary guide used with the Sigma High Performance Partial Knee group. After finishing the bone work, the soft tissue of the flexion and extension gap was balanced. All pieces from the bone resection of the femur and tibia were harvested and the bone resection weight of each unicompartmental knee prosthesis design was calculated. The tibia and femoral components were cemented with Simplex P bone cement (Stryker Company [*Kalamazoo, MI, USA]). All patients received fosfomycin for two days as infection prophylaxis and were managed with mechanical rather than chemical thromboprophylaxis.

Patient evaluation

1) Bone resection weight. All pieces of bone resection from the femoral and tibial sections of both component designs were harvested by the same surgeon and weighed at the end of the operation using a medical analytical balance and compare the two component designs.

2) Clinical evaluation. All patients in both groups were evaluated pre-operatively and post-operatively at one, three, and six months, and at one and two years using Knee Society knee and functional scores[16,17]. Range of motion [ROM] was recorded pre-operatively and during follow-ups over a period of two years; any complications were recorded. Surgical time, blood loss, incision length, and length of hospital stay were also recorded.

3) Radiographic evaluation. Postoperative knee alignment was assessed using a scanogram to determine the location in the knee through which the mechanical axis passed and was classified following Kennedy and White[18].

Statistical analysis

Sample size was calculated based on the difference in mean bone resection weight (22 grams and 15.9 grams for fixed-bearing UKA and mobile-bearing UKA, respectively). The standard deviation was 5 grams. Sixteen knees in each group would have 80% power at the 5% significant level. Randomization was carried out using the block randomization technique. Descriptive data was reported as mean and standard deviation which were compared between the two groups using the Wilcoxon-Mann-Whitney test for statistical difference.

Results

Average age at the time of surgery was 66 years in the mobile-bearing group and 65 years in the fixed-bearing group (Table 1). There was no significant

Table 1. Patient Demographic data for fixed-bearing and mobile-bearing UKA

Characteristic	Fixed-bearing group	Mobile-bearing group	*p*-value
Number of patients	20	20	-
Mean age (years)	65 (4.25)	66 (4.30)	0.986
Male (%)	5 (25)	8 (40)	0.311
Female (%)	15 (75)	12 (60)	0.311
Right (%)	13 (65)	9 (45)	0.064
Left (%)	7 (35)	11 (55)	0.064
Weight (kg)	66.45 (13.94)	66.27 (11.71)	0.860
Height (cm)	156.40 (6.53)	159.20 (8.50)	0.386
Body mass index (BMI)	26.99 (5.21)	26.26 (4.66)	0.685
Etiology			
OA	20	20	-

difference in average age between the two groups (*p* = 0.986). The average weight and BMI were 66.27 kg and 26.26 kg/m^2 in the mobile-bearing group, and 66.45 kg and 26.99 kg/m^2 in the fixed-bearing group. Twelve of the patients (60%) in the mobile-bearing group were females and eight (40%) were males; in the fixed-bearing group, 15 (75%) were females and five (25%) were males (Table 1). The difference in male/female ratios of the two groups was not statistically significant. In the mobile-bearing group nine right knees (45%) and 11 left knees (55%) underwent surgery, while in the fixed-bearing group there were 13 right knees (65%) and seven left knees (35%) (Table 1). All patients were diagnosed with osteoarthritis as the cause of knee damage.

The average operation time in the fixed-bearing group, 63.40 minutes, was significantly shorter than the 69.90 minutes in the mobile-bearing group (*p* = 0.004). Similarly, the fixed-bearing had a greater bone-resection weight, 22.0 mg, than the mobile-bearing weight of 15.90 mg, a statistically significant difference (*p* = 0.002) (Table 2). That difference may be due to the different bone resection technique used with the femoral part in each group. A milling technique was used in the mobile-bearing UKA group, while a standard bone-cut was used in the fixed-bearing UKA group.

For the other factors measured, there were no statistically significant differences between the groups. The average blood loss from the post-operative redivac drain was 166.50 cc in the mobile-bearing group compared to 128.50 cc in those in the fixed-bearing group (*p* = 0.161). Neither group had any patients who required a blood transfusion. The average post-operative length of stay was also not significantly different: the mobile-bearing group average post-operative hospitalization was 5.5 days versus 5.5 days for the fixed-bearing group (*p* = 0.270) (Table 2).

The average Knee Society scores and Functional scores at one, three, and six months and at one and two years post-operation were not significantly different for the two groups (*p* = 0.775). [*The average Knee Society scores were 84.15 at one month, 89.20 at three months, 95.75 at six months, 98.94 at one year and 99.87 at two years in the mobile-bearing UKA group] (Figure 1). For the fixed-bearing UKA group the scores were 83.75 at one month, 91.00 at three months, 96.00 at six months, 98.4 at one year and 100 at two years (Figure 2).

The Functional score at one month was 80.25, 87.95 at three months, 94.35 at six months, and 99.06 and 97.67 at one year and two years, respectively, in the mobile-bearing UKA group, while the fixed-bearing UKA group scores were 81.25 at one month, 88.00 at three months, 94.55 at six months, 99.73 at one year, and 98.60 at two years (*p* = 0.967) (Figure 2).

The average of range of motion [ROM] in the fixed-bearing group was slightly higher than that of the mobile-bearing group, with a mean range of 111 degrees at one month, 123 degrees at three months and 128 degrees at six months post-operation versus the mobile-bearing UKA results of 110 degrees at one month, 121 degrees at three months, and 127 degrees at six months post-operation. However, after two years the difference between the two groups was not

Table 2. Intra-operative and post-operative clinical results

Clinical	Fixed-bearing	Mobile-bearing	*p*-value
Operative time (min)			
Surgical time (bone-cut)	31.25 (3.68)	37.15 (6.18)	0.001
Tourniquet time	63.40 (5.12)	69.90 (7.57)	0.004
Bone resection weight (grams)	22.00 (5.48)	15.90 (5.40)	0.002
Blood loss (drain) (cc)	128.50 (48.80)	166.50 (87.74)	0.161
Wound length (cm)	7.05 (0.63)	7.45 (0.89)	0.179
Length of stay (days)	5.50 (1.52)	5.50 (0.69)	0.270
Range of motion (degrees)			
Pre-operation	106.75 (9.63)	113.00 (19.12)	0.101
Post-operation (ROM 1 month)	111.00 (8.21)	110.00 (14.99)	0.736
Post-operation (ROM 3 months)	123.00 (5.03)	121.00 (12.81)	0.867
Post-operation (ROM 6 months)	128.00 (3.39)	127.00 (12.18)	0.556
Post-operation (ROM 1 year)	130.33 (3.12)	131.56 (11.95)	0.953
Post-operation (ROM 2 years)	132.33 (2.86)	132.00 (11.32)	0.838

statistically significant ($p = 0.838$). The post-operative radiological outcomes showed a majority of neutral or slightly valgus patients in the mobile-bearing group. There were 15 post-operative mechanical axis alignments (75%) in Zone C, four (20%) in Zone II, and one (5%) in Zone III. There was a slightly neutral or varus trend in the fixed-bearing group, which had 14 post-operative mechanical axis alignments (70%) in Zone II, four (20%) in Zone C, and two (10%) in Zone I using the Kennedy and White classification (Table 3).

Three instances of adverse conditions occurred in this study. One patient in the fixed-bearing group had a tibial plateau fracture which was identified at the first month follow-up and treated using conservative techniques: a knee brace and protective weight bearing. Another patient, in the mobile-bearing group, had a stitch abscess with superficial wound infection at the two-week follow-up which was treated with oral antibiotics, wound dressing, and patient reassurance. A third patient had a bearing dislocation while kneeling three months post-operation; it was revised with thicker polyethylene. All three continued in the study.

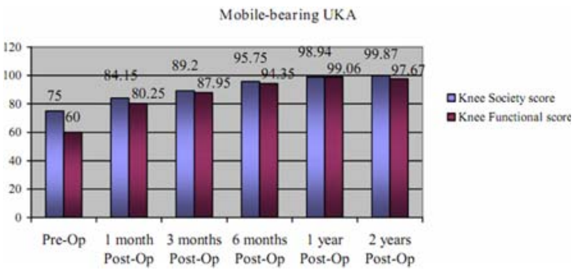

Figure 1. Average Knee score and Functional score of mobile-bearing UKA at follow-up.

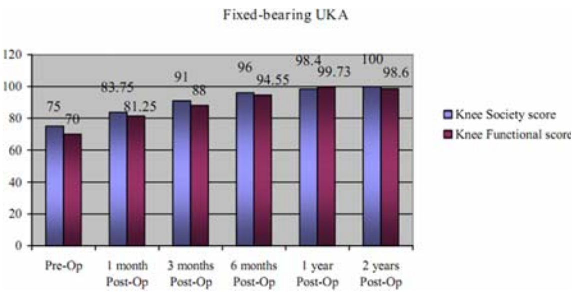

Figure 2. Average Knee score and Functional score of Fixed-bearing UKA at follow-up

Discussion

Unicompartmental knee arthroplasty remains one of several surgical options for the treatment of isolated medial compartment arthritis of the knee. Successful survivorship has been reported over the midterm for both mobile-and fixed-bearing UKA designs[6,19-21], but Goodfellow et al suggested that a mobile-bearing design reduces bone prosthesis stress at the tibial surface[2,22] and results in improved long-term survivorship. However, no studies have demonstrated that the early clinical outcome of a mobile-bearing UKA is better than that of a fixed-bearing UKA. In our study we wanted to know how mobile- and fixed-bearing UKA differ in terms of clinical outcomes, post-operative knee alignments, and x-ray alignments as well as bone preservation, (particularly bone resection weight which has never been reported).

From the study results several important observations can be made, each of which has been reported in previous studies comparing fixed- and mobile-bearing UKA results. In 2002, Emerson et al[8] in a retrospective comparison of 51 UKA with fixed tibial bearings and 50 UKA with mobile-bearings found no difference in the clinical outcomes based on Knee Society scores. However, in this study the Knee Society scores in the fixed-bearing group were slightly higher than in the mobile-bearing group, although no significant clinical advantage was found between fixed- and mobile-bearing tibial components.

No previous study has reported surgical times for operations with fixed-bearing and mobile-bearing

Table 3. Mechanical axis according to the Kennedy and White classification

Kennedy classification	Fixed-bearing UKA	Mobile-bearing UKA
Kennedy 1	2 (10%)	-
Kennedy 2	14 (70%)	4 (20%)
Kennedy C	4 (20%)	15 (75%)
Kennedy 3	-	1 (5%)

UKA. This study found the average operation times in the mobile-bearing group were significantly higher than the fixed-bearing group. Our hypothesis is that this time difference may be due to several reasons stemming from the fact that mobile-bearings involve more challenging surgical procedures and require more precise tibial and femoral bone cutting, principally as well as soft tissue and gap balancing, factors which if not sufficiently accurate can contribute to serious problems, particularly bearing dislocation.

The authors found that mobile-bearing UKA had a significantly lower bone resection weight than the fixed-bearing UKA which was correlated with the different surgical techniques. In particular, in the mobile-bearing design, gap balancing is done first using the flexion gap then by milling the femoral bone using a spigot in 1 mm increments to insure the extension and flexion gaps are equal. If the flexion gap is smaller, distal femoral bone milling, which is correlated with flexion gap, will result in less bone removal from the distal femur.

The thickness of the majority of the mobile-bearing inserts in this study were 3 to 4 mm. Another reason is that spigots are very precise bone cutting instruments which cannot move forward more than the planning size, which could preserve more bone than techniques used with the fixed-bearing group, which getting the large pieces of distal femoral bone from the chamfer design instrument. However, the implant size might be affected by the amount of bone removed. While there is an advantage in bone preservation with a mobile-bearing UKA, average blood loss in the mobile-bearing group was greater than in the fixed-bearing group, a result of reaming the distal femur rather than the resurfacing done with a fixed-bearing UKA. The reaming might leave exposed raw bone that could be a source of post-operative bleeding.

Although a key principal of UKA surgery is avoiding overcorrection, this study found that mechanical axis alignment as measured using the Kennedy and White system resulted in a smaller fraction of the mobile-bearing group Zone 2. For this reason, in mobile-bearing UKA surgery it might be preferable to create a slightly tight knee balance in the soft tissue to reduce the risk of meniscal bearing dislocation. However, with fixed-bearing UKA a 1 to 2 mm gap may be preferred. So far, the mechanical axes are different in both groups. Among possible complications, bearing dislocation has been a main cause of failure in mobile-bearing UKA(12). In our study, one patient had bearing dislocation while kneeling; we found slight looseness in the flexion gap which was corrected with thicker polyethylene. A devastating adverse effect was a tibial fracture in fixed-bearing UKA which occurred because we recut the tibial surface when the tibial bone resection was inadequate, creating new pin holes and resulting in more than three holes in the tibial cutting block. We hypothesize that the diameter and the number of pin holes, particularly those in or near the vertical slot, may have contributed to the decreased bone strength. The situation was additionally aggravated by the patient's premature ambulation. Brumby et al(23) reported tibial stress fractures after UKA which were attributed to drilling four holes for the placement of guide pins in addition to holes for tibial preparation. If the tibial bone has to be recut, not only should very special consideration should be given to hole diameter and a small smooth diameter pin should be used when recutting the tibial surface. It is important to be aware of the placement of new pin holes in the vertical slot and to be careful to keep the saw blade close to the posterior cortex of the tibial plateau.

Our study included some limitations. First, the follow-up period of only two years precluded drawing conclusions about long term wear and patient satisfaction (previous studies, however, have reported excellent long-term survivorship). Second, a larger sample size would have been preferable.

Conclusion

Better bone preservation and a less constrained design are among the advantages of the mobile-bearing UKA, but there are no differences in early clinical outcomes between fixed- and mobile-bearing UKA. Advantages of the fixed-bearing UKA include the relative ease of the operation, the safety of the procedure, and the lower postoperative blood loss. Key to success in UKA operations lies with appropriate patient selection, precise surgical technique, and proper implant selection.

What is already known on this topic?

Studies have reported excellent results and survivorship in the treatment of medial compartment osteoarthritis with both fixed-bearing UKA and mobile-bearing UKA unicompartmental knee arthroplasty.

What this study adds?

Bone preservation, first reported in this study, was found to be significantly better in mobile-bearing UKA, providing arthroplasty surgeons additional information for use in the selection of unicompartmental knee prosthesis methods.

Potential conflicts of interest

The authors have no conflicts of interest.

References

1. Insall J, Walker P. Unicondylar knee replacement. Clin Orthop Relat Res 1976;(120):83-5.
2. Goodfellow JW, O'Connor J. Clinical results of the Oxford knee. Surface arthroplasty of the tibiofemoral joint with a meniscal bearing prosthesis. Clin Orthop Relat Res 1986;(205):21-42.
3. Berger RA, Meneghini RM, Jacobs JJ, Sheinkop MB, Della Valle CJ, Rosenberg AG, et al. Results of unicompartmental knee arthroplasty at a minimum of ten years of follow-up. J Bone Joint Surg Am 2005;87:999-1006.
4. Naudie D, Guerin J, Parker DA, Bourne RB, Rorabeck CH. Medial unicompartmental knee arthroplasty with the Miller-Galante prosthesis. J Bone Joint Surg Am 2004;86-A:1931-5.
5. Argenson JN, Chevrol-Benkeddache Y, Aubaniac JM. Modern unicompartmental knee arthroplasty with cement: a three to ten-year follow-up study. J Bone Joint Surg Am 2002;84-A:2235-9.
6. Murray DW, Goodfellow JW, O'Connor JJ. The Oxford medial unicompartmentalarthroplasty: a ten-year survival study. J Bone Joint Surg Br 1998;80:983-9.
7. Svard UC, Price AJ. Oxford medial unicompartmental knee arthroplasty. A survival analysis of an independent series. J Bone Joint Surg Br 2001;83:191-4.
8. Emerson RH Jr, Higgins LL. Unicompartmental knee arthroplasty with the oxford prosthesis in patients with medial compartment arthritis. J Bone Joint Surg Am 2008;90:118-22.
9. Lewold S, Goodman S, Knutson K, Robertsson O, Lidgren L. Oxford meniscal bearing knee versus the Marmor knee in unicompartmentalarthroplasty for arthrosis. A Swedish multicenter survival study. J Arthroplasty 1995;10:722-31.
10. Li MG, Yao F, Joss B, Ioppolo J, Nivbrant B, Wood D. Mobile vs. fixed bearing unicondylar knee arthroplasty: A randomized study on short term clinical outcomes and knee kinematics. Knee 2006;13:365-70.
11. Gleeson RE, Evans R, Ackroyd CE, Webb J, Newman JH. Fixed or mobile bearing unicompartmental knee replacement? A comparative cohort study. Knee 2004;11:379-84.
12. Confalonieri N, Manzotti A, Pullen C. Comparison of a mobile with a fixed tibial bearing unicompartimental knee prosthesis: a prospective randomized trial using a dedicated outcome score. Knee 2004;11:357-62.
13. Kozinn SC, Scott R. Unicondylar knee arthroplasty. J Bone Joint Surg Am 1989;71:145-50.
14. Ahlback S. Osteoarthrosis of the knee. A radiographic investigation. Acta Radiol Diagn (Stockh) 1968;Suppl 277:7-72.
15. Outerbridge RE. The etiology of chondromalacia patellae. J Bone Joint Surg Br 1961;43-B:752-7.
16. Insall JN, Dorr LD, Scott RD, Scott WN. Rationale of the Knee Society clinical rating system. Clin Orthop Relat Res 1989;(248):13-4.
17. Ewald FC. The Knee Society total knee arthroplastyroentgenographic evaluation and scoring system. Clin Orthop Relat Res 1989;(248):9-12.
18. Kennedy WR, White RP. Unicompartmentalarthroplasty of the knee. Postoperative alignment and its influence on overall results. Clin Orthop Relat Res 1987;(221):278-85.
19. Marmor L. Unicompartmental knee arthroplasty. Ten- to thirteen-year follow-up study. Clin Orthop Relat Res 1988;(226):14-20.
20. Scott RD, Santore RF. Unicondylar unicompartmental replacement for osteoarthritis of the knee. J Bone Joint Surg Am 1981;63:536-44.
21. Squire MW, Callaghan JJ, Goetz DD, Sullivan PM, Johnston RC. Unicompartmental knee replacement. A minimum 15 year followup study. Clin Orthop Relat Res 1999;(367):61-72.
22. Buechel FF, Pappas MJ. Long-term survivorship analysis of cruciate-sparing versus cruciate-sacrificing knee prostheses using meniscal bearings. Clin Orthop Relat Res 1990;(260):162-9.
23. Brumby SA, Carrington R, Zayontz S, Reish T, Scott RD. Tibial plateau stress fracture: a complication of unicompartmental knee arthroplasty using 4 guide pinholes. J Arthroplasty 2003;18:809-12.