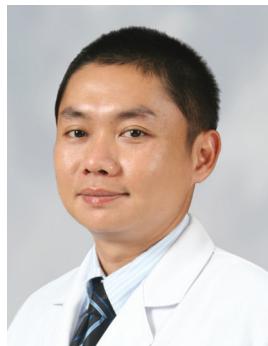


## Resurgence of Unicompartmental Knee Arthroplasty



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**D**uring the 1970's and 1980's, Orthopaedic Surgeons began developing and using unicondylar knee arthroplasty (UKA) for treatment of unicompartmental osteoarthritis (OA) of the knee.<sup>1</sup> High failure rates were reported, due to poor design (mostly due to the cement loosening and plastic wear), poor surgical technique, and improper patient selection.<sup>2-5</sup>

In contrast, high promising results of total knee arthroplasty (TKA) were reported from many studies.<sup>6-11</sup> When UKA results were compared to TKA, the UKA fell out of favor with many surgeons. By the 1990's TKA was considered to have become the standard treatment of knee osteoarthritis.

However, UKA continued to be used. There has been a renewal of interest in UKA, due to emerging minimally invasive techniques, improvement of instrumentation and design rationales together with increased understanding of biomechanics, and proper patient selection.

Recently there have been many comparative studies between TKA and UKA. Most results report UKA provides better functional outcomes, earlier recovery, ease of revision and lower costs.<sup>12-17</sup>

### The Concept and Philosophy

The philosophy behind UKA is much different to that of TKA. In osteoarthritis of the knee, the knee malalignment (from either varus or valgus deformities) is due to articular cartilage loss and ligament laxity. Using the TKA technique, alignment is corrected by cutting the bone, which changes the knee anatomy to achieve mechanical axis of the lower limb.

UKA will not cut the bone to achieve mechanical axis but uses instead the composite thickness of the prosthetic unicompartmental components (thickness of polyethelene) to correct limb alignment (Figure 1).

The advantages for UKA are a less invasive surgery and shorter hospital stay. The range of motion is usually better than for total knee arthroplasties and proprioception is not impaired. Other benefits include better kinematics, quicker recovery and the bone stock is preserved, thus making revision easier.<sup>18</sup> Newman, et al., showed in a randomized study that UKA had less perioperative morbidity, patients both recovered faster, and gained more flexion; however the loosening rate was similar to TKA.<sup>19</sup> The Oxford Group has shown similar results in studies in which UKA was compared with TKA; furthermore, their results showed that recovery was even faster if a small incision was used.<sup>20, 21</sup> Results from the Swedish Knee Registry showed that the UKA procedure was more

cost-effective than TKA, even taking into account the increased risk for revisions.<sup>22</sup>

Considering the factors which cases are amenable to surgery, according to Deschamps's statement: *"there are five types of indications to take into account. These are the age of the patient, the patient's activity level, weight, and ligamentous status (particularly the central pivot), and lastly, the severity of the deformity. The ideal indication for a UKR is a low demand patient over 60 years of age; the UKR is particularly recommended in old or sedentary patients. The patient should weigh less than 85 kg, but the Body Mass Index (BMI) should also be taken into account. The central pivot should be intact. The deformity should be moderate and, above all, reducible without overcorrection (varus-valgus shift when taking stress views). The residual deformity (if any) after correction should not exceed 5 degree varus in a varus knee and 5 degree valgus in a valgus knee"*<sup>23</sup>

### Design

Presently, two designs of UKA are available, fixed bearing and mobile bearing UKA but there is controversy over which design provides superior results. The first design of UKA, with more than 30 years of clinical use, was fixed bearing. The first implant was Mammor prosthesis.

Fixed bearing prosthetics come in two types: metal backing design (Figure 1) and all polyethylene (Figure 2). The metal back design provides better load distribution and load transfer to the bone but it needs more cutting.



**Figure 1:** Metal-Back Design.

The all polyethylene tibial component design requires less bone to be cut which means a greater remaining bone stock. Although this has the potential for good results, the literature suggests there may be a higher rate of early loosening and failure due to the thin cement mantle needed to fix the component in place.<sup>24</sup>

A report by Small, et al., showed all polyethylene designs significantly increased tibial strain which led to tibial subsidence. An in vitro biomechanical model was established to measure strain on tibial bone surface. The results showed implantation with all polyethylene tibial components resulted in higher strain measurements across the medial surface of the proximal tibia. Statistically significant increases in maximum shear strain ranged from 57% to 223% ( $p < 0.05$ ).<sup>25</sup> Although many studies show promising results over the long term, there are still aspects to be concerned about with the mobile bearing designs, such as the frequency of radiolucent lines in metal back tibial components, or the more frequent need for gap balancing techniques or the risk of bearing dislocation.<sup>26,27</sup>

### Mobile Bearing Design

Much of the recent literature reports excellent long term results with specific mobile bearing UKA design (Oxford; Biomet, Warsaw, Figure 3) with increasing use of mobile bearing knee. The polyethylene bearing is not fixed to the metal back; instead it acts like the meniscus and can move along the metal back. The mobile meniscal bearing allows contact over a large area, which ought to then minimize contact stresses, shear forces, and probably polyethylene wear.



**Figure 2:** All Polyethelene design.



**Figure 3:** The tibial components are made from cobalt chromium molybdenum alloy. Six sizes are available for both the left and right side, for maximum coverage on tibial bone cut and to avoid anteromedial overhang, which sometimes caused postoperative pain in the Phase 2 design.



**Figure 4:** The femoral components (single radius design) are made of cast cobalt chromium molybdenum alloy for strength, wear resistance and biocompatibility. The design is available in 5 sizes.



**Figure 5:** The articulating surface of the femoral component is spherical and polished to a very high tolerance.

Retrieval analysis suggests that the edge loading effect of flat on flat articulation of most fixed bearing designs is the cause of polyethylene wear. Therefore some designs of fixed bearing UKA tried to increase conformity of articulation. However these attempts led to an increased, loosening rate of femoral and tibial components; more conformity actually caused additional strain to implants and the bone interface. The mobile bearing design by comparison reduces the strain on the bone interface.

### Changing Indications for UKA

Kozinn and Scott described the classic indications for UKA in 1989. Using these stringent criteria, results improved significantly, although these criteria actually excluded 90-95% of patients with knee arthritis.<sup>28</sup> With improvements in surgical technique, (such as minimally invasive methods) and better designs of UKA with enhanced longevity and durability, recovery time was

significantly reduced. Hospitalization is now often reduced to 1-2 days, and recovery time to 2-4 weeks.<sup>29-33</sup> UKA indications could be expanded to include use as a temporizing procedure in younger patients with unicompartmental arthritis.<sup>31, 34, 35</sup> (Table 1). Some treatment centers claim that up to 30% of their knee arthritis patients now receive UKAs.<sup>36</sup>

A UKA may be appropriate for younger patients as a temporizing procedure. The option for conversion to a TKA is reasonable due to reduced bone loss making revision easier.<sup>37</sup> As Carlson and Albrektson pointed out, “*UKA yields results comparable with TKA. Because of the high level of patient satisfaction and the lower incidence of complications and morbidity compared with TKA, UKA is an attractive alternative for patients with predominantly unicompartmental, noninflammatory arthritis. Patient interest in UKA is enhanced by the adaptation of the operative procedure to a minimally invasive incision with the possibility of outpatient surgery*”.<sup>18</sup>

**Table 1:** UKA indications.

Characteristics	Classic indications	Evolving indications
Age (years)	> 60	> 50 as temporizing measure > 60 as definitive procedure
Weight (kg)	< 82	Yet undefined
Activity level	Low demand	Non-laborers
Arthritis location	Purely medial or lateral	Purely medial or lateral
Diagnosis	Non-inflammatory, non-crystalline	Non-inflammatory, non-crystalline; Ahback stage 1,2 or 3 (not 4) osteoarthritis
Range of motion		
Flexion	> 90°	> 90°
Flexion contracture	< 5°	< 15°
Deformity		
Varus	< 10°	Passively correctible to within 5° of neutral mechanical axis
Valgus	< 15°	
ACL	Intact without mediolateral subluxation	OK if attenuated or absent due to attrition; no gross clinical instability
Patellofemoral joint	No symptoms; minimal chondromalacia	Minimal symptoms; no sclerosis of patellar facet; mild/moderate degenerative changes
Symptoms	Unicompartmental; abate with rest	OK if a symptomatic Unicompartmental

### Results of Unicompartmental Arthroplasty

Although early to midterm studies cited a high rate of satisfactory results after UKA, long-term survivorship and outcomes continue to be a concern.<sup>38</sup> Many recent studies have reported good long term results after improvements in UKA design and more rigorous attention being given to patient selection criteria and improved surgical techniques.

Price AJ, et al.,<sup>39</sup> reported the survival rate at 20 years of Oxford knee design; 510 Oxford UKA was enrolled in the study. The 10 and 20 year survival rates were 94% and 91% respectively. They reported 29 revision procedures were performed: 10 for lateral arthrosis, nine for component loosening, five for infection, two bearing dislocations, and three for unexplained pain. No failure rate from patellofemoral problem was seen, which implies that patellofemoral arthritis was not a contraindication for UKA. It was also noted that there were very low rates of revision due to polyethylene wear related complications, which suggested low wear from fully congruent mobile designs of UKA.

Keblish and Briard<sup>40</sup> conducted a nonblinded review of 177 patients with LCS mobile bearing knee (DEPUY) from two centers, 137 from USA, and 44 from France, which were followed up over 11 years. All patients and radiographics were evaluated preoperatively, immediately post operative, then at 6 months and yearly until complications occurred. They reported overall good and excellent results in 82% of cases and fair/poor results in 18% of cases using the Hospital for Special Surgery Knee Rating Scale. Thirty two complications were found in this series. The most common failures in this study were bearing failures, which occurred in first generation polyethylene with design errors. Fifteen cases were revised by polyethylene exchange. Polyethylene wear with oxidative changes and varying degrees of splits/cracks of the articulating surface were noted in all cases. The authors suggested periodic x-rays were necessary in order to detect polyethylene failure at an earlier stage, especially for first generation designs (made between 1985 and the late 1990's), because the polyethylene exchange procedure was easier and more cost effective than revision of all components.

Several comparative studies of TKA and UKA have looked at the short and long term results with regard to aspects such as patient satisfaction, survival rate and cost. Most studies show better functional outcomes faster recovery, ease of revision and lower cost for UKA.

A recent study from Lombardi AV, et al.,<sup>41</sup> did a matching comparison (in terms of incidence of complication and manipulation, postoperative function and time needed for return to work) between 103 (115 patients) Mobile bearing UKA performed with minimally invasive technique and 103 (115 patients) cruciate retaining TKA. Post hoc power analysis revealed sufficient power to detect the variables studied at 80%. The UKA group had better range of motion at discharge and shorter hospital stay than TKA group (77 versus 67 and 1.4 versus 2.2 days). At 6 weeks, Knee Society functional scores and range of motion were higher for UKA than TKA (63 versus 55 and 115 degrees versus 110 degrees). The conclusion was that minimally invasive UKA demonstrated better early ROM, shorter hospital stays, and improved functional scores.

Recently, numerous reports detail the advantages of minimally invasive technique for UKA. This approach is performed with a small incision, but without dislocation of the patella, leaving the quadriceps tendon intact, and is therefore conducive to a faster recovery. Muller PE, et al.,<sup>42</sup> performed a comparative study between 30 minimal invasive approach and 30 standard approaches for UKA in terms of implant position and functional results. The mobile bearing oxford knee was implanted in all cases. Data from the study shows better functional outcome with significant higher score of HSS scores in the minimally invasive group; the minimally invasive technique did not show negative effect for implant positioning. So, they recommended minimally invasive technique should be the method of choice. Price et al.,<sup>43</sup> compared recovery rates by the time it took for patients to be able to do straight leg raising, and ability to climb stairs between 40 Oxford UKA with minimally invasive approach and 20 Oxford UKA with standard UKA; both groups were then compared to 40 of Anatomic Graduated Component (AGC) TKA. The results show average rate of recovery after minimal invasive UKA was twice as fast as after standard UKA and 3 times as fast as after total knee arthroplasty. All postoperative radiographic tests in minimal invasive UKA group show similar accuracy of implantation. This demonstrates that the minimally invasive technique can achieve both good short and long term results after UKA.

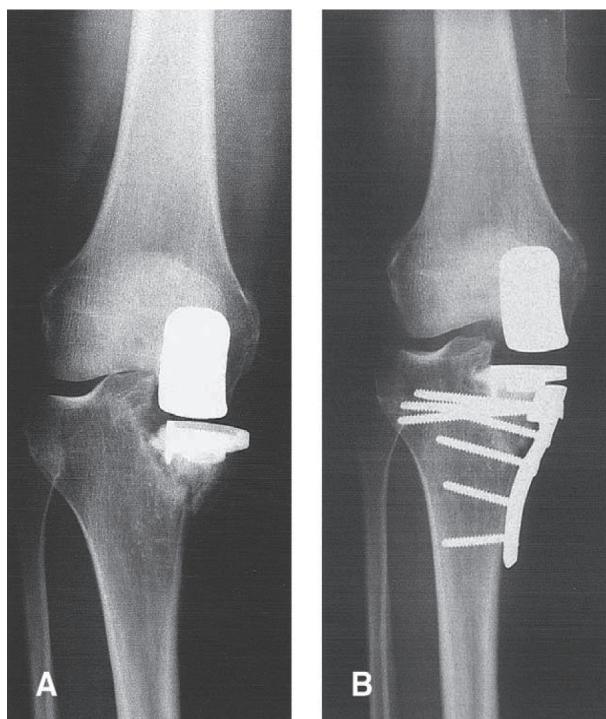
### Potential Problems

There are many potential factors related to the longevity of UKA, such as patient activity levels, body habitus, intact cruciate ligaments, postoperative alignment, soft tissue balancing, implant positioning and design.<sup>43-48</sup> These factors can lead to many complications.

### Fracture of Medial Tibial Plateau

Berger RA, et al.,<sup>49</sup> reported complications due to tibial fractures in 51 knees after UKA at minimum 6 years follow up. All UKAs were performed using the Miller-Galante fixed bearing design (Zimmer Warsaw). His series had 4 fractures of medial tibial fracture, 3 cases which occurred intraoperatively and one case occurring 6 weeks post op. Vince and Cyran<sup>50</sup> noted that some fractures “*may require more extensive open reduction and internal fixation and others revision by arthroplasty. These fractures might be avoidable by limiting the number and location of pin holes that are created in securing cutting instruments to the proximal tibia*”.

Yang, et al.,<sup>51</sup> reported a case of a 63-year-old woman (Figure 6 A-B) with medial compartment osteoarthritis who initially had limited deformity. Within 3 months of surgery, medial tibial plateau fracture had displaced. Considerable amounts of bone were missing and there was the possibility of extensive avascular necrosis. Revision arthroplasty would have been difficult. Figure 6 B shows open reduction and internal fixation has been performed. This procedure is extensive, surgical, and involves wide exposure.



**Figure 6 A-B:** Demonstrates a case of OA which underwent open reduction and internal fixation due to excessive bone loss.

Brumby SA, et al.,<sup>52</sup> reported the 4 cases of medial tibial plateau fracture after UKA. Tibial cutting jig was fixed to the bone by 4 guide pins, which reduced compressive strength and caused stress fracture in all 4 cases. They recommended “*avoiding multiple guide pin holes in the proximal tibia for UKA. This can be achieved by using one centrally placed pin in association with another form of stabilization such as a clamp at the ankle. Furthermore, a tibial cutting jig that can be adjusted to take a thicker cut using the same guide pins should be used. If 3 or more pin holes are deemed necessary for UKA, surgeons must be aware of the potential for tibial stress*”.

### Bearing Dislocation

The Oxford mobile bearing UKA has a 10% bearing dislocation rate as reported by the center where it was developed. Moo-Ho Song, et al.,<sup>53</sup> retrospectively reviewed the first 100 consecutive minimally invasive mobile-bearing UKA using Oxford knee design, with mean follow up time of 24 months: all surgeries used the minimally invasive medial parapatella approach. Four cases of bearing dislocation were reported, which were corrected by changing to a thicker polyethylene bearing. They suggested the main cause of bearing dislocation was inequality of flexion and extension gap, another potential cause was delayed elongation of MCL and osteophyte impingement.

A multicenter review identified performed by the Swedish Orthopaedics Society, the failure pattern was identified in 699 cases with Oxford Knee.<sup>54</sup> The results show the main reasons for revision surgery were “*dislocating meniscus in 16 cases, loosening of the femoral component in 6, tibia component in 4, both components in 4, contralateral arthrosis in 10, infection in 4, and technical failure with instability, pain, and/or impingement of the meniscal bearing anterior in the femoral condyle in 6*”. The authors reported dislocation of the menisci was caused mainly by thin components and/or malposition of the implants which may occur ventrally in the femoral condyle by the menisci.

### Lateral compartment progression

Much of the literature reported one common cause of revision in UKA was progression of disease to contralateral side, mostly due to surgical technique.

Price AJ, et al.,<sup>42</sup> reviewed the long term results of 510 Oxford mobile bearing UKA's performed during 1983-2005; the survival rate at 10 years was 94% and at 20 years was 91%. The most common cause of failure was the progression of arthritis of lateral compartment (10 patients or 1.5%). They reported that the cause of rapid deterioration of lateral compartment was over correction of alignment. The reason for lower reported rates of lateral progression, reflects successful surgical techniques that did not attempt to overcorrect alignment.

Bert JM<sup>55</sup> studied ten year survival rates of medial UKA performed with Fixed bearing design (Biomet, Warsaw) between 1985-1987. The survival rate at ten years was 87.4% in 95 UKAs. The most common cause of failure in this series was lateral compartment disease after 5 years (Figure 7). Ten cases were revised due to lateral disease progression; eight of these cases had tibiofemoral angles greater than 5 degree valgus, but only two cases had tibiofemoral angles of less than 4.5 degrees. In cases with overcorrection, there was a higher rate of progression of lateral compartment.

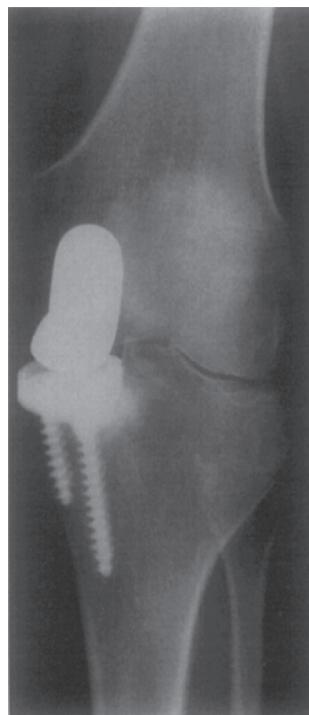
Hernigou P and Deschamps G<sup>56</sup> did a retrospective radiographic review of 156 medial UKA performed with Lotus (Mark 1). They divided the patients in three groups depending on their HIP-KNEE-ANKLE angle.

Group I had an angle of more than 180 degrees, group II's angle was between 170-180 degree and group III's angle less than 170 degrees. A higher than average rate of cartilage wear was found in group I (0.23 mm/year). However in group III, a significant high rate of polyethylene wear was also found (0.21 mm/year). They confirmed significant rapid OA change on lateral compartment can occur where there has been overcorrection alignment of preexisting varus deformity and advise to avoid overcorrection more than 180 degree on HIP-KNEE-ANKLE angle.

### Summary

Renewed interest in UKA is the result of improving minimally invasive techniques and implant designs, as well as improvement of instrumentation. The literature clearly shows the benefits of minimally invasive UKA: rapid recovery time, less blood loss, less disruption of soft tissue, shorter hospital stay, faster return range of motion and function, and without any impairment effect on implant alignment.

In well selected patients, with isolated medial compartment knee arthritis, minimally invasive UKA can be the procedure of choice when performed with meticulous technique by a well trained surgeon.



**Figure 7:** Progressive increased lateral compartment pain.

Femoral tibial angle increased to 12° at 6.5 years after surgery.

## References

1. Repicci JA, Hartman JF. Minimally invasive unicondylar knee arthroplasty for the treatment of unicompartmental osteoarthritis: an outpatient arthritic bypass procedure. *Clin Orthop N* 2004;35:201-16.
2. Insall J, Aglietti P. A five- to seven-year follow-up of unicondylar arthroplasty. *J Bone Joint Surg Am* 1980;62:1329-37.
3. Ackroyd CE, Whitehouse SL, Newman JH, et al. A comparative study of the medial St Georg sled and kinematic total knee arthroplasties. Ten year survivorship. *J Bone Joint Surg Br* 2002;84:667-72.
4. Barrett WP, Scott RD. Revision of failed unicondylar unicompartmental knee arthroplasty. *J Bone Joint Surg Am* 1987;69:1328-35.
5. Dennis DA, Clayton ML, O'Donnell S, et al. Posterior cruciate condylar total knee arthroplasty. Average 11-year follow-up evaluation. *Clin Orthop* 1992;281:168-76.
6. Ranawat CS, Boachie-Adjei O. Survivorship analysis and results of total condylar knee arthroplasty. Eight- to 11-year follow-up period. *Clin Orthop* 1988;226:6-13.
7. Ritter MA, Campbell E, Faris PM, et al. Long-term survival analysis of the posterior cruciate condylar total knee arthroplasty. A 10-year evaluation. *J Arthroplasty* 1989;4:293-6.
8. Scuderi GR, Insall JN, Windsor RE, et al. Survivorship of cemented knee replacements. *J Bone Joint Surg Br* 1989;71:798-803.
9. Stern SH, Insall JN. Posterior stabilized prosthesis. Results after follow-up of nine to twelve years. *J Bone Joint Surg Am* 1992;74:980-6.
10. Vince KG, Insall JN, Kelly MA. The total condylar prosthesis. 10- to 12-year results of a cemented knee replacement. *J Bone Joint Surg Br* 1989;71:793-7.
11. Hassaballa MA, Porteus AJ, Learmonth ID. Functional outcomes after different types of knee arthroplasty: Kneeling ability versus descending stairs. *Med Sci Monit* 2007;13:77-81.
12. Hassaballa MA, Porteus AJ, Newman JH, et al. Can knees kneel? Kneeling ability after total, unicompartmental and patellofemoral arthroplasty. *Knee* 2003;10:155-60.
13. Laurencin CT, Zellicof SB, Scott RD, et al. Unicompartmental versus total knee arthroplasty in the same patient. A comparative study. *Clin Orthop Relat Res* 1991;273:151-6.
14. Manzotti A, Confalonieri N, Pullen C. Unicompartmental versus computer-assisted total knee replacement for medial compartment knee arthritis: a matched pair study. *Int Orthop* 2007;31:315-9.
15. Walton NP, Jahromi I, Lewis PL, et al. Patient-perceived outcomes and return to sport and work: TKA versus miniincision unicompartmental knee arthroplasty. *J Knee Surg* 2006;19:112-6.
16. Weale AE, Halabi OA, Jones PW, et al. Perceptions of outcomes after unicompartmental and total knee replacements: *Clin Orthop Relat Res* 2001;382:143-53.
17. Weale AE, Murray DW, Crawford R, et al. Does arthritis progress in the retained compartments after 'Oxford' medial unicompartmental arthroplasty? A clinical and radiological study with a minimum ten year follow-up. *J Bone Joint Surg Br* 1999;81:783-9.
18. Carlsson LV, Albrektsson BEJ. Minimally Invasive Surgery vs Conventional Exposure Using the Miller-Galante Unicompartmental Knee Arthroplasty, A Randomized Radiostereometric Study. *The Journal of Arthroplasty* 2006;21:151-16.
19. Newman JH, Ackroyd CE, Shah NA. Unicompartmental or total knee replacement? Five-year results of a prospective, randomised trial of 102 osteoarthritic knees with unicompartmental arthritis. *J Bone Joint Surg Br* 1998;80:862.
20. Price AJ, Webb J, Topf H, et al. Rapid recovery after Oxford unicompartmental arthroplasty through a short incision. *J Arthroplasty* 2001;16:970.
21. Beard DJ, Murray DW, Rees JL, et al. Accelerated recovery for unicompartmental knee replacement feasibility study. *Knee* 2002;9:221.
22. Robertsson O, Borgqvist L, Knutsson K, et al. Use of unicompartmental instead of tricompartmental prostheses for unicompartmental arthrosis in the knee is a cost-effective alternative. 15,437 primary tricompartmental prostheses were compared with 10,624 primary medial or lateral unicompartmental prostheses. *Acta Orthop Scand* 1999;70:170.
23. Deschamps G. Unicompartmental knee arthroplasty Technical principles. *Osteoarthritis of the knee*. France: Springer 2008:113-24.
24. Bonutti P, Marker D, Ulrich S, et al. Evaluation of an all-polyethylene tibial component design in unicompartmental knee arthroplasty. AAOS: San Francisco (Calif);2008.
25. Small SR, Berend ME, Ritter MA. Metal Backing Significantly Decreases Tibial Strains in a Medial Unicompartmental Knee Arthroplasty Model. *The Journal of Arthroplasty* 2010;10:771-6.
26. Price A, Wait J, Svärd U. Long-term clinical results of the medial Oxford unicompartmental knee arthroplasty. *Clin Orthop Rel Res* 2005;171-80.
27. Vorlat P, Putzeys G, Cottenie D, et al. The Oxford unicompartmental knee prosthesis: an independent 10-year survival analysis. *Knee Surg Sports Traumatol Arthrosc* 2005;14:40-5.
28. Kozinn SC and Scott R. Unicondylar knee arthroplasty. *J Bone Joint Surg* 1989;71:145-50.
29. Cameron HU, Hunter GA, Welsh RP, et al. Unicompartmental knee replacement. *Clin Orthop* 1981;160:109-13.
30. Repicci JA and Ebrle RW. Minimally invasive surgical technique for unicondylar knee arthroplasty. *J South Orthop Assoc* 1999;8:20-7.
31. Romanowski MR and Repicci JA. Minimally invasive unicondylar arthroplasty (eight-year follow-up). *J Knee Surg* 2002;15:17-22.
32. Lindstrand A, Stenstrom A, Ryd L, et al. The introduction period of unicompartmental knee arthroplasty is critical. *J Arthroplasty* 2000;15:608-16.
33. Keys GW. The reduced invasive approach for medial Oxford II meniscal bearing replacement. *J Bone Joint Surg Br* 2000;82 (Suppl 1):24-5.
34. Price AJ, Webb J, Topf H, et al. Rapid recovery after Oxford uni-compartmental arthroplasty through a short incision. *J Arthroplasty* 2001;16:970-97.
35. Engh GA. Orthopaedic crossfire-can we justify unicondylar

arthroplasty as a temporizing procedure? In the affirmative. *J Arthroplasty* 2002;17 [Suppl 1]:54-5.

36. Mont MA, Stuchin SA, Paley D, et al. Different surgical options for monocompartmental osteoarthritis of the knee: high tibial osteotomy versus unicompartmental knee arthroplasty versus total knee arthroplasty: indications, techniques, results, and controversies. *Instr Course Lect* 2004; 53:265-83.

37. Padgett DE, Stern SH, Insall JN. Revision total knee arthroplasty for failed unicompartmental replacement. *J Bone Joint Surg Am* 1991;73:186-90.

38. Inglis GS. Unicompartmental arthroplasty of the knee: a follow up of 3 to 9 years. *J Bone Joint Surg Br* 1984;66: 682-84.

39. Price AJ and Svard U: A Second Decade Lifetable Survival Analysis of the Oxford Unicompartmental Knee Arthroplasty. *Clin Orthop Relat Res* 2010; 382:143-53.

40. Keblish PA and Briard JL: Mobile Bearing Unicompartmental Knee Arthroplasty, A 2-Center Study With an 11-Year (Mean) Follow-Up: *The Journal of Arthroplasty* 2004;19(Suppl.2):87-94.

41. Lombardi AV, Berend KR, Walter CA, et al. Is Recovery Faster for Mobile-bearing Unicompartmental than Total Knee Arthroplasty?: *Clin Orthop Relat Res* 2009; 467:1450-7.

42. Muller PE, Pellengahr C, Witt M, et al. Influence of Minimally Invasive Surgery on Implant Positioning and the Functional Outcome for Medial Unicompartmental Knee Arthroplasty. *The Journal of Arthroplasty* 2004; 19:296-301.

43. Price AJ, Webb J, Topf H, et al. Rapid Recovery After Oxford Unicompartmental Arthroplasty Through a Short Incision. *The Journal of Arthroplasty* 2001;16 :970-6.

44. Barrett W and Scott R. Revision of failed unicondylar unicompartmental knee arthroplasty. *J Bone Joint Surg* 1987;69:1328-35.

45. Collier MB, Eickmann TH, Sukezaki F, et al. Patient, implant, and alignment factors associated with revision of medial compartment unicondylar arthroplasty. *The Journal of Arthroplasty Annual AAHKS Meeting, November 2005 Scientific Program* 2006;21:108-15.

46. Kennedy WR and White RP. Unicompartmental arthroplasty of the knee. Postoperative alignment and its influence on overall results. *Clin Orthop Relat Res* 1987;221:278-85.

47. Aleto TJ, Berend ME, Ritter MA, et al. Early failure of unicompartmental knee arthroplasty leading to revision. *J Arthroplasty* 2008;23:159-63.

48. Barrett W, Scott R. Revision of failed unicondylar unicompartmental knee arthroplasty. *J Bone Joint Surg* 1987; 69:1328-35.

49. Berger RA, Nedeoff DD, Barden RM, et al. Unicompartmental knee arthroplasty: clinical experience at 6- to 10-year followup. *Clin Orthop* 1999; 367:50.

50. Vince KG, Cyran LT: Unicompartmental knee arthroplasty New Indications, More complications? *J Arthroplasty* 2004;19:12.

51. Yang KY, Yeo SJ, Lo NN. Stress fracture of the medial tibial plateau after minimally invasive unicompartmental knee arthroplasty: a report of 2 cases. *J Arthroplasty* 2008;18:801.

52. Brumby SA, Carrington R, Zayontz S, et al: Tibial plateau stress fracture: a complication of unicompartmental knee arthroplasty using 4 guide pinholes. *J Arthroplasty* 2003;18:809.

53. Song MH, Kim BH, Ahn SJ , et al. Early Complications After Minimally Invasive Mobile-Bearing Medial Unicompartmental Knee Arthroplasty. *The Journal of Arthroplasty* 2009; 248:1281-4.

54. Lewold S, Knutsom K, Robertsson O, et al. Oxford Meniscal Bearing Knee versus the Marmor Knee in Unicompartmental Arthroplasty for Arthrosis (A Swedish Multicenter Survival Study). *The Journal of Arthroplasty* 1995;10:722-31.

55. Bert JM. 10-Year Survivorship of Metal Backed Unicompartmental Arthroplasty. *The Journal of Arthroplasty* 1998;13:901-5.

56. Hernigou P and Deschamps G. Alignment Influences Wear in the Knee after Medial Unicompartmental Arthroplasty. *Clinical Orthopaedics and Related Research* 2004;423:161-5.