Clinical outcome of unicompartmental knee arthroplasty and influence of alignment on prosthesis survival rate

Kasodekar V B, Yeo S J, Othman S

ABSTRACT

Introduction: Various factors that affect the longevity of unicompartmental knee arthroplasty (UKA) include patient activity level, habitus, competence of cruciate ligaments, postoperative alignment, implant positioning and ligament balancing. The purpose of this study was to evaluate the clinical outcome of the open standard UKA and establish the influence of radiological alignment on the survivorship of the prosthesis.

Methods: We consecutively reviewed the results of 20 open standard UKAs performed in 17 patients between 1996 and 2000. A single implant type, the Press Fit Condylar Unicompartmental Knee System (DePuy, Leeds, UK), was used in all patients. All patients were evaluated clinically using the Knee Society Rating. Implant positioning and limb alignment were recorded in the standing long leg anteroposterior and lateral radiographs, and various angles were measured.

Results: The alignment of the prosthesis was found to be good in 19 out of 20 operated knees. One knee with malalignment of prosthesis had to be revised at 23 months follow-up. There was a significant increase in Knee Society Rating of all patients, at a follow-up of 4-8 years. The Kaplan-Meier survival rate using revision to total knee arthroplasty as an endpoint was 91.7 percent.

Conclusion: The long-term outcome of UKA is influenced by positioning and alignment of the prosthesis. With proper patient selection and surgical technique, the outcome of UKA can be definitely improved.

Keywords: arthroplasty, knee alignment, knee arthroplasty, prosthesis, unicompartmental knee arthroplastsy

Singapore Med J 2006; 47(9):796-802

INTRODUCTION

Unicompartmental knee arthroplasty (UKA) was introduced by Marmor in early 1970s[1]. It has been advocated for different reasons in two patient groups. The first patient group includes younger individuals with unicompartmental disease in which UKA may be preferred to high tibial osteotomy (HTO). It has been suggested that UKA is a bone-sparing operation that will later allow an uncomplicated revision. To date, revision of previous UKA has not demonstrated this anticipated benefit. Barrett and Scott reported that significant bone grafting, tibial wedges or long stem components were necessary in 45% of revisions[2], while Padgett et al found major osseous defects in 76% of knees at time of revision[3]. Difficulties with exposure and slightly less satisfactory clinical outcomes have been reported with total knee arthroplasty (TKA) after previous HTO, when compared with primary TKA[4].

The other type of patients for whom UKA has been advocated is the elderly, thin individual with unicompartmental disease who would otherwise undergo TKA. The suggested benefits of UKA over TKA are a shorter rehabilitation time, a greater average postoperative arc of motion[5], and preservation of proprioceptive function of the cruciate ligaments, which gave a more naturally feeling knee[6]. However, to date, UKA has not had the same rate of survivorship as TKA. Scott et al reported 91% survivorship at nine years, but this fell to 53% at 12 years[7].

Another argument favouring TKA over UKA is the rarity that a given surgeon would perform UKA. According to Stern et al, only 6% of patients needing arthroplasty have none of the contraindications to UKA[8]. Because the success of the procedure is dictated by the technical performance of the operation, surgeons who rarely perform UKA may have difficulty reproducing the reported results from large reconstructive centres. While the indications for UKA are debatable, the contraindications are fairly definite. According to Kozinn and Scott, they are: inflammatory arthritis, a flexion contracture of more

Department of Orthopaedic Surgery
Singapore General Hospital
Outram Road
Singapore 169608

Kasodekar V B, MD
Clinical Associate

Yeo S J, MD, FRCS
Senior Consultant

Othman S, MD
Fellow in Adult Reconstruction

Correspondence to:
Dr Yeo Seng Jin
Tel: (65) 6321 4040
Fax: (65) 6224 8100
Email: gocysj@sgh.com.sg

than 5 degrees, a preoperative arc of motion of less than 90 degrees, angular deformity of more than 15 degrees, significant cartilaginous erosions in weight-bearing areas of the opposite compartment, anterior cruciate ligament deficiency, and exposed subchondral bone beneath the patella[9].

Although several authors have reported more than 90% survivorship at ten years[10-13], Insall and Aglietti reported a 28% revision rate in 24 knees[14], with an average six years follow-up[14]. Laskin reported that only 65% of his patients had significant pain relief, and revision was needed in eight of 37 knees (21%)[15]. Other authors have shown variability in the failure rate at intermediate-term and long-term follow-up. This variability continues to contribute to the controversy about clinical outcome of UKA.

The causes of early failure are multifactorial and include poor patient selection and surgical technique[16], inadequate implant design[17], polyethylene wear[18], inaccurate instrumentation[19] and poor understanding of knee kinematics. With improvement in all these aspects, long-term studies in the 1990s found that the survivorship of an UKA approaches that of TKA[20]. The studies also identified various factors that affect the longevity of UKA and these include: patient activity level, habitus, competence of cruciate ligaments, postoperative alignment and implant positioning, and ligament balancing. While the adversities in the first three factors can be avoided by proper patient selection, the surgeon decides on the final alignment and ligament balancing with proper surgical technique and hence the long-term outcome of UKA. The purpose of this study was to evaluate the clinical outcome of the open standard UKA, and establish the influence of alignment on long-term survivorship of the prosthesis.

METHODS

We reviewed the results of 20 consecutive open standard UKAs performed in 17 patients between 1996 and 2000. The surgeries were performed in a tertiary care government hospital in Singapore by the senior author. The patient demographics are listed in Table I. Of the 17 patients (20 knees), one died and one was lost to follow-up, leaving us with 15 patients and 18 knees.

The surgical approach involved a formal medial parapatellar arthrotomy of 15-20 cm in length. Medial osteophytes were removed from the femur and tibia but no ligamentous release was performed. The tibial resection was made perpendicular to its long axis with an extra-medullary guidance system, while the distal femoral resection was based on an intra-medullary rod. The posterior femoral resection then created a flexion gap equal to the extension space. Thickness of the polyethylene was adjusted to ensure a well-balanced knee capable of full extension.

Table I. Summary of patient demographics in open unicompartmental knee arthroplasty.

Parameter	Open UKA
Number of patients	20
Age (range)	59.6 years (47-73 years)
Male:female ratio	1:19
Weight (range)	62.7 kg (39-84 kg)
Right:left ratio	11:9
Medial:lateral UKA	19:1
All poly:metal back ratio	18:2

A single implant type, the Press Kit Condylar Unicompartmental Knee System (DePuy, Leeds, UK) was used in all patients. This was a fixed-bearing design with an all-polyethylene tibial component. A metal-backed tibial component option was available when the combined tibial component thickness is 10 mm and above. Both femoral and tibial components were cemented in all cases. All patients were evaluated clinically using the Knee Society Rating[21], which included pain, range of motion and stability and functional score, preoperatively and postoperatively at their latest follow-up.

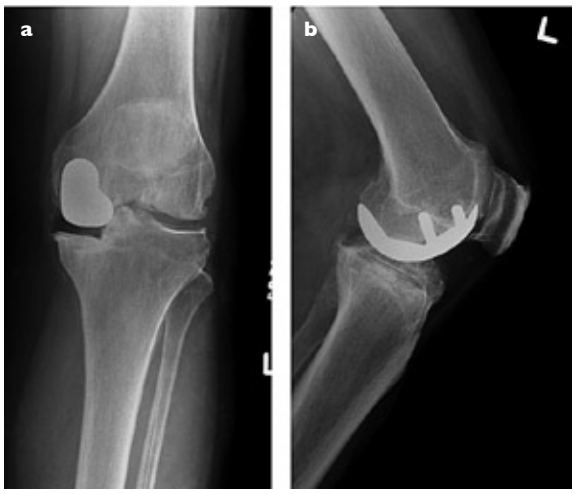

Fig. 1 Postoperative (a) AP and (b) lateral radiographs of UKA done in 1996.

All the patients had anteroposterior (AP) and lateral radiographs of the knees taken preoperatively, three months postoperatively, and yearly. Although there were a series of follow-up radiographs, we compared the radiographs at the latest follow-up (Fig. 1). The radiographs were standardised to avoid any aberrations arising from knee rotation. In the AP weight-bearing view, the knee was in full extension

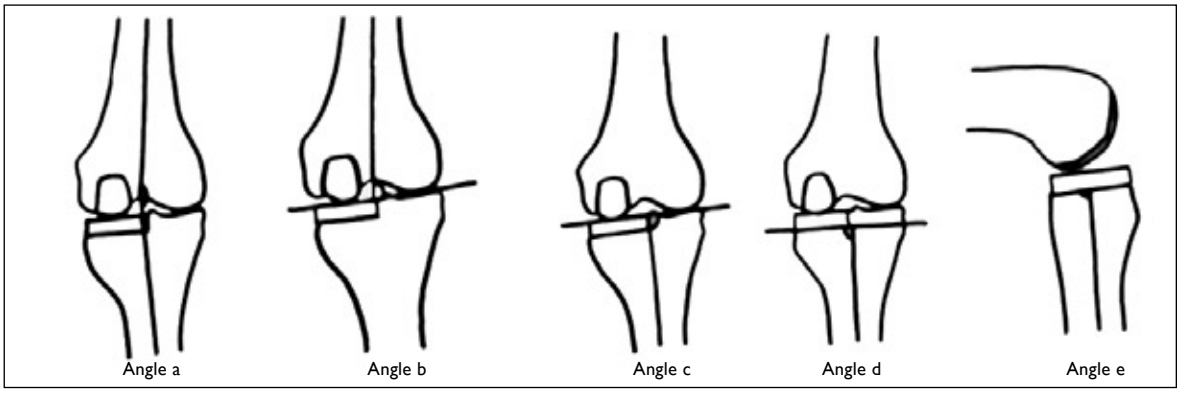

Fig. 2 Radiographical parameters evaluated on AP and lateral view are: (a) tibiofemoral angle; (b) femoral joint line orientation; (c) tibial joint line orientation; (d) prosthesis-tibial angle; (e) posterior tibial slope.

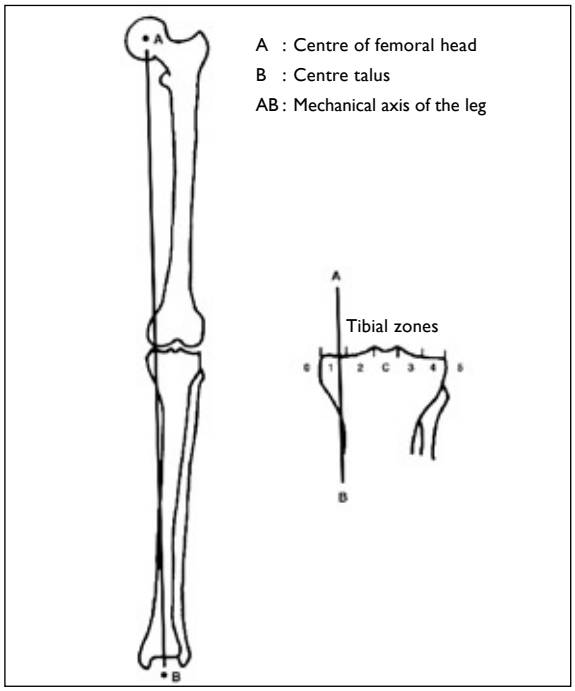

Fig. 3 Kennedy and White zone-specific criteria for limb alignment.

and the patella was centralised over the trochlea. The lateral view was taken with the knee in 45 degrees of flexion. Pre- and postoperative radiographs were compared and the following parameters were evaluated: (1) tibiofemoral angle; (2) distal femoral joint line orientation; (3) proximal tibial joint line orientation; (4) prosthesis-tibial angle in the coronal plane and (5) posterior tibial slope angle (Fig. 2).

We also defined our radiographical objectives for the above parameters based on the available outcome studies. For the limb alignments, we adopted the zone-specific criteria, which was originally described by Kennedy and White[22], and subsequently modified by Perkins and Gunckle[23]. The alignments were classified according to the zone on the tibial plateau, through which the mechanical axis passes: (1) zone 0 corresponds to a tibiofemoral angle of 3-7 degrees varus; (2) zone 1, 0-2 degrees varus; (3) zone 2, 1-2 degrees valgus; (4) zone C, 3-6 degrees valgus; (5) zone 3, 7-10 degrees valgus; (6) zone 4, 11-14.5 degrees and (7) zone 5, >15 degrees valgus (Fig. 3). It has been found that the patients with a tibiofemoral angle of 1-6 degrees valgus had the longest survivorship.

Besides the tibiofemoral angle, we also measured the postoperative joint line orientation. Normally, there is 3 to 4 degrees of varus inclination with respect to tibial axis[24]. After UKA, the proximal tibial joint line orientation is solely determined by the relative height of the medial to the lateral tibial plateau. For UKA, which is a surface replacement, our objective is to implant the medial tibial plateau 2 mm below the lateral plateau[25], with 2 to 5 degrees of varus tibial inclination. Similarly, a normal distal femoral joint line carries approximately 8 to 9 degrees of anatomic valgus. In an UKA, the femoral joint line is dependent on the relative depth of the medial femoral component to that of intact lateral condyle. We accept values between 7 to 10 degrees of valgus as ideal to complement our varus tibial inclination. It is important to note that the joint line orientation can vary independently to the tibiofemoral angle.

The position of tibial implant (prosthesis-tibial angle) is also important, irrespective of the tibio-femoral angle and joint line orientation achieved. In the coronal plane, the medial tibial plateau is resected perpendicular to the axis of the tibia. Based on a previous outcome study[26], we defined the range of prosthesis-tibial angle of 87 to 93 degrees as being optimal. Finally, we also aimed to restore the posterior tibial slope in the sagittal plane. We based our values on the study by Moller et al who found that the anatomical reconstruction of the posterior tibial slope gave the best outcome[27]. In their cadaveric study, the majority of the specimens had a posterior tibial slope of 8 to 11 degrees, with a median of 10 degrees to the anatomical axis of the tibia. The ideal measurements are observed in follow-up of a case at eight years (Fig. 4).

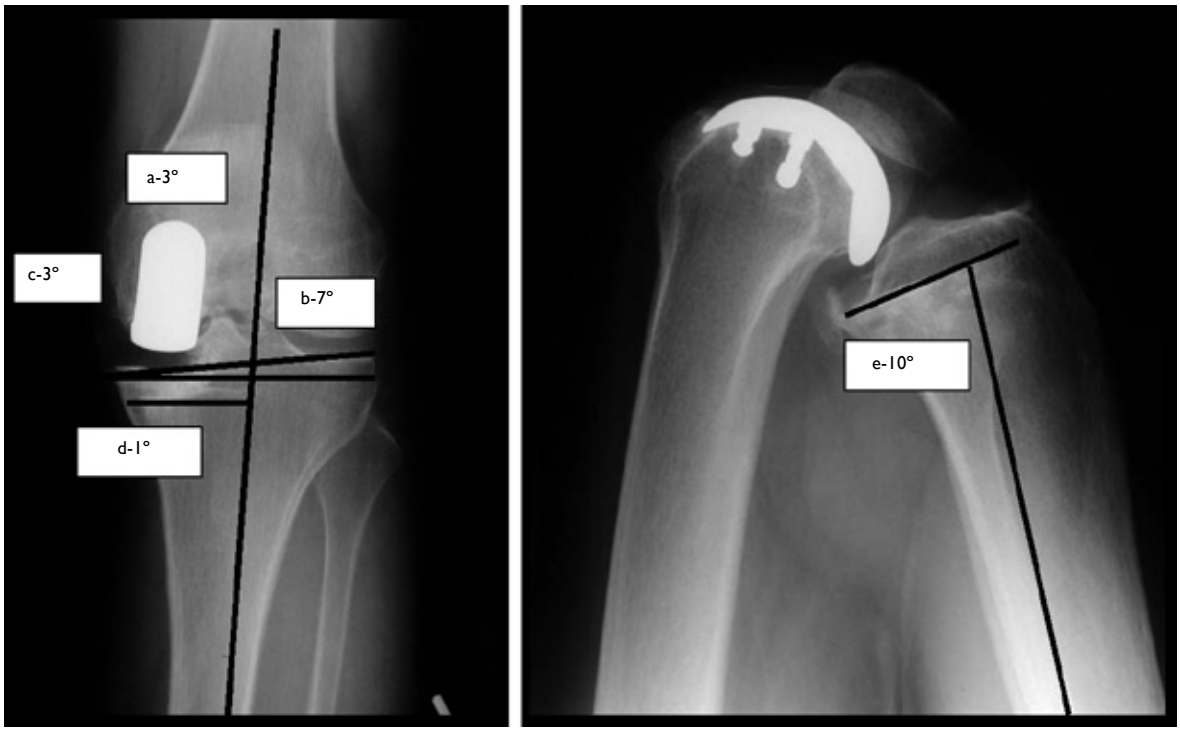

Fig. 4 Postoperative radiographs of UKA done in a 56-year-old man shows ideal alignment angles and excellent range of movement. (Patient had preoperative knee score and functional score of 56 and 50, and postoperatives score of 96 and 94, respectively).

The Kaplan-Meier four-year survivorship analysis was done and we included the knee of the deceased in this analysis, as the patient did not have any problems with the knee before death. The person lost to follow-up after six years was also included in the survivorship analysis. The statistical analysis was done using Statistical Package for the Social Sciences (SPSS) version 10.1.3 (Chicago, IL, USA). For the Knee Society Rating, the mean preoperative and postoperative values were compared using the two-tailed t-test with the significance level set at the $p<0.05$. In addition, the Knee Society knee score was also analysed using the chi-square test. The survival of the prosthesis was determined using Kaplan-Meier survival rate at the end of four years, with revision to total knee arthroplasty as the endpoint.

RESULTS

The radiographical alignment analysis showed that postoperatively, the distal femur joint line orientation was at a mean angle of 7 degrees valgus (range 5-11 degrees valgus) with 2.5 standard deviation (SD) (ideal value in 85%). The proximal tibial joint line was at 3.2 degrees varus (range 2-5 degrees varus) with 1.2 SD (ideal value in 100%). The prosthesis tibial angle was 2.2 degrees varus (range 1-3 degrees varus) with 1.0 SD (ideal value in 100%), and the posterior slope of tibia was at 8.4 degrees (range, 6-11 degrees) with 2.6 SD (ideal value in 90%). 100% of patients fulfilled three or more criteria (Table II).

Table II. Measurement of various angles in UKA.

Mean preoperative alignment	2.8 degrees varus (SD 2.5) range 13 degrees varus - 8 degrees valgus
Mean postoperative alignment	2.3 degrees valgus (SD 2) range 1 degree varus - 8 degrees valgus
Proportion with ideal value 1-6 degrees valgus	17/20 = 85%
Mean distal femoral angle	7 degrees valgus (SD 2.5) range 5-11 degrees valgus
Proportion with ideal value 7-10 degrees valgus	17/20 = 85%
Mean proximal tibial angle	3.2 degrees varus (SD 1.2) range 2-5 degrees varus
Proportion with ideal value 2-5 degrees varus	20/20 = 100%
Mean prosthesis tibial angle	2.2 degrees varus (SD 1.0) range 1-3 degrees varus
Proportion with ideal value 3 degrees varus - 3 degrees valgus	20/20 = 100%
Mean posterior slope	8.4 degrees (SD 2.6) range 6-11 degrees
Proportion with ideal value 8-11 degrees slope	20/20 = 100%
Fulfilling 3 or more criteria out of 5	20/20= 100%

The mean Knee Society knee score for the 15 patients (18 knees), who were living and who had not undergone any procedure, improved significantly from 48.6 (range 38-58) to 88.8 (range 68-96). The Functional Score improved from 59.4 (range 40-70) to 89.7 (range 65-100) at the time of latest follow-up (p<0.0001) (Table III). The average range of motion improved from 121.9 degrees (range 90-130 degrees) to 133.8 degrees (range 100-150 degrees) (p<0.05).

In 19 medial unicompartmental arthritic knees, the preoperative femorotibial angle of 2.8 degrees varus (range 13 degrees varus to 8 degrees valgus) was corrected to 2.3 degrees valgus (range 1 degree varus to 8 degrees valgus) at the time of latest evaluation. In one lateral unicompartmental knee arthroplasty, the preoperative femorotibial angle of 7 degrees valgus was corrected to 6 degrees valgus (three knees were outside the ideal range of postoperative alignment (one with 1 degree varus and two others with 8 degrees valgus) (Table IV).

Incomplete radiolucent lines were seen on the initial and final radiographs in 29.4% of knees (80% were tibial), but these lines were <2 mm and were not significant. The final survivorship analysis included 19 knees. One knee required revision to total knee arthroplasty, secondary to aseptic loosening at 23 months (Fig. 5). The Kaplan-Meier four-year survival rate, with revision to total knee arthroplasty as an endpoint, was 91.7%.

Table III. Knee Society Rating in open UKA at 4-8 years follow-up.

Parameter	Preoperative	Postoperative (statistical significance)
Pain/range of motion/ stability	48.6 range 38-58	88.8 (p<0.0001) range 68-96
Functional score	59.4 range 40-70	89.7 (p<0.0001) range 65-100

Table IV. Distribution of patients as per zone specific criteria for limb alignment.

Zone	No. of patients
0	0
I	I
2	4
C	13
3	2
4	0
5	0

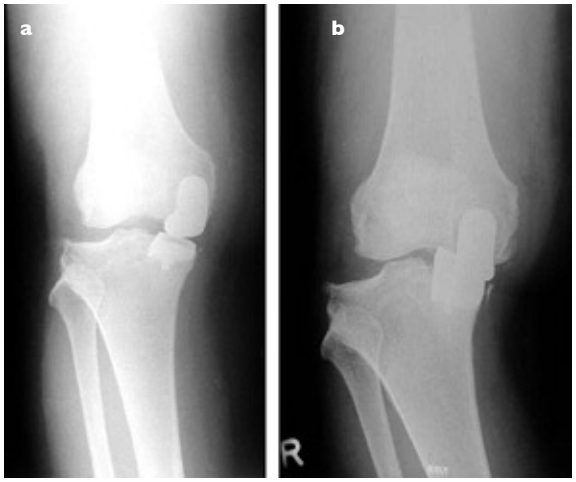

Fig. 5 Postoperative AP radiographs of UKA show (a) edge loading due to malalignment of prosthesis compared with (b) a good alignment in another patient.

DISCUSSION

The purpose of this retrospective study was to report the intermediate-term results of unicompartmental knee arthroplasty and establish the influence of alignment on long-term survivorship of the prosthesis. At 4-8 years follow up, this series of 20 UKAs yielded statistically significant clinical outcome. In this series, one failure was observed. Early failure occurred primarily as a result of aseptic loosening in both the femoral and tibial components. This early failure probably occurred as a result of a functionally-deficient anterior cruciate ligament due to degenerative process, and the distal femoral angle which was in excess of valgus leading to edge loading and polyethylene wear. This patient was treated with conversion to total knee arthroplasty, with no augmentation procedure required.

The average Knee Society knee score for 15 patients (18 knees), who were living and who had not undergone any procedure, improved significantly from 48.6 (range 38-58) to 88.8 (range 68-96). The Functional Score improved from 59.4 (range 40-70) to 89.7 (range 65-100) at the time of latest follow-up (p<0.0001). The average range of motion improved from 121.9 degrees (range 90-130 degrees) to 133.8 degrees (range 100-150 degrees) (Fig. 4). We attribute our good results to careful patient selection and radiographical alignment of the prosthesis.

The contraindications for UKA, as highlighted by Kozinn and Scott[9], were strictly observed and we attribute the longevity of prosthesis to proper selection of patients. Patellofemoral symptoms were considered to be a contraindication to UKA, and no failure was observed because of progression to patellofemoral disease. This finding is in contrast

to that of Argenson et al[28], who did not consider the status of patellofemoral joint as a selection criterion. In that study, progression of patellofemoral arthritis was reported in 60% of the knees.

The radiographical alignment analysis showed that postoperatively, the proximal tibial joint line, the prosthesis tibial angle and the posterior slope of tibia were all within the ideal range of values. Three of the knees had mean postoperative tibiofemoral angles not falling within the ideal range. One knee had to be revised to total knee replacement (case of earlier failure at 23 months). One knee had a postoperative tibiofemoral angle of 1 degree varus. This knee has the follow-up of five years and there was no sign of any excess poly wear on medial side. The probable reason for the good result could be due to decreased activity level and lean built. The patient was a 71-year-old and did only household activities. The third knee had 8 degree valgus and is showing some changes in the lateral compartment but the patient is asymptomatic.

The accuracy of implantation is an accepted prognostic factor for long-term survival of UKA. In open UKA, although anatomical landmarks are easily identified, the system offers a limited and potentially-inaccurate instrumentation, which relies on substantial surgeon judgment for prosthesis placement. Rates of inaccurate implantation of 30% have been reported with such instrumentation[29]. Failure of medial unicompartmental arthroplasty may be related to wear of the cartilage in the opposite compartment, or to wear and tear in the polyethylene insert. Limb alignment influences both these factors in long-term results of UKA[30,31].

The outcome of UKA is also enhanced by optimum joint line orientation of the distal femur and proximal tibia. We consider the UKA to be a resurfacing operation, and aim to restore the anatomical joint line orientation by placing the medial tibial plateau slightly more distal than the lateral plateau, as highlighted by Lootvoet et al[25]. A normal orientation has the advantage of preservation of normal knee kinematics especially with intact cruciate ligaments. Excessive tibial resection results in a lower medial plateau and increased varus tibial inclination, while under-resection produces a valgus orientation.

While there is much literature available on the improving outcome and longevity of UKA, the contributions of surgical technique, post-operative alignment and prosthesis placement to the survivorship is less clear. Kennedy and White found that patients with postoperative alignment that is slightly under-corrected had the longest survivorship[22]. Over-correction into excessive mechanical valgus tends to place excessive stress on the lateral compartment[32]. On the other hand, some authors concluded that neutral alignment is optimal as under-correction leads to increased polyethylene wear[32]. However, this posed a problem, mainly for patients with thin polyethylene of less than 8 mm. We believe that with adequate polyethylene thickness, slight varus alignment will give the best long-term results. In the coronal plane, it is desirable for the tibial tray to be perpendicular to the axis of the tibia. Sitting the implant perpendicular to the mechanical axis minimises the shear at the interface during weight-bearing. Swienckowski and Page found that when there was more than 3 degrees deviation of the tibial tray from the perpendicular of the tibial axis, the clinical result worsened significantly[18] .

Through their cadaveric study, Moller et al established the median anatomical tibial slope in the sagittal plane to be 10 degrees[27]. They further assessed the effect of posterior slope on the kinematics of UKA. When the tibial implant was placed without any posterior slope, there was posterior articulation of the femoral component on the tibial tray at all degrees of flexion. This resulted in posterior marginal loading that produced a rocking-horse phenomenon during the early stance phase at 0-20 degrees of flexion. It also restricted the range of motion with excessive contact stress during deep flexion.

Conversely, with an anatomical posterior tilt of 10 degrees, the result was optimal central tibial articulation and loading. This was confirmed clinically by Swienckowski and Page, who found that patients with 9 degrees of posterior slope had the best Hospital for Special Surgery (HSS) score and Marmor clinical rating. The outcome deteriorated with excessive (>11 degrees) or inadequate (<8 degrees) posterior slope. Furthermore, the combination of the prosthesis-tibial angle and posterior tibial slope had a cumulative effect. Patients deviating from the ideal range for both these angles had much higher failure rates than the patients who had only deviation of either one plane.

In conclusion, the four-year survival rate of 91.7% with good Knee Society knee rating and radiographical alignment in the present series have led the authors to believe that there is definite influence of radiographical alignment on outcome of UKA. Continued long-term follow-up of these patients may renew enthusiasm for this procedure.

REFERENCES

1. Marmor L. Unicompartmental knee arthroplasty: Ten- to 13-year follow-up study. Clin Orthop Relat Res 1988; (226):14-20.
2. Barrett WP, Scott RD. Revision of failed unicompartmental knee arthroplasty. J Bone Joint Surg Am 1987; 69:1328-35.
3. Padgett D, Stern SH, Insall JN. Revision total knee arthroplasty for failed unicompartmental replacement. J Bone Joint Surg Am 1991; 73:186-90.
4. Amendola A, Rorabeck CH, Bourne RB, Apyan PM. Total knee arthroplasty following high tibial osteotomy for osteoarthritis. J Arthroplasty 1989; 4 suppl:S11-7.
5. Repicci JA. Total knee or uni? Benefits and limitations of unicondylar knee prosthesis. Orthopedics 2003; 26:274-7.
6. Engh GA, Ammeen D. Is an intact anterior cruciate ligament needed in order to have a well-functioning unicondylar knee replacement. Clin Orthop Relat Res 2004; (428):170-3.
7. Scott RD, Cobb AG, McQueary FG, Thornhill TS. Unicompartmental knee arthroplasty: Eight- to 12-year follow up evaluation with survivorship analysis. Clin Orthop Relat Res 1991; (271):96-100.
8. Stern SH, Becker MW, Insall JN. Unicondylar knee arthroplasty. An evaluation of selection criteria. Clin Orthop Relat Res 1993; (286):143-8.
9. Kozinn SC, Scott RD. Unicondylar knee arthroplasty. J Bone Joint Surg Am 1989; 71:145-50.
10. Berger RA, Nedeff DD, Barden RM, et al. Unicompartmental knee arthroplasty. Clinical experience at 6- to 10-year followup. Clin Orthop Relat Res 1999; (367):50-60.
11. Capra SW Jr, Fehring TK. Unicondylar arthroplasty. A survivorship analysis. J Arthroplasty 1992; 7:247-51.
12. Christensen NO. Unicompartmental prosthesis for gonarthrosis. A nine-year series of 575 knees from a Swedish hospital. Clin Orthop Relat Res 1991; (273):165-9.
13. Squire MW, Callaghan JJ, Goetz DD, Sullivan PM, Johnston RC. Uniconpartmental knee replacement. A minimum 15 year followup study. Clin Orthop Relat Res 1999; (367):61-72.
14. Insall J, Aglietti P. A five to seven-year followup of unicondylar arthroplasty. J Bone Joint Surg Am 1980; 62:1329-37.
15. Laskin RS. Unicompartmental tibiofemoral resurfacing arthroplasty. J Bone Joint Surg Am 1978; 60:182-5.
16. Bernasek TL, Rand JA, Bryan RS. Unicompartmental porous coated anatomic total knee arthroplasty. Clin Orthop Relat Res 1988; (236): 52-9.
17. Lindstrand A, Stenstrom A. Polyethylene wear of the PCA unicompartmental knee. Prospective 5 (4-8) year study of 120 arthrosis knees. Acta Orthop Scand 1992; 63:260-2.
18. Swienckowski J, Page BJ 2nd. Medial unicompartmental arthroplasty of the knee. Use of the L-cut and comparison with the tibial inset method. Clin Orthop Relat Res 1989; (239):161-7.
19. Murray DW, Goodfellow JW, O'Connor JJ. The Oxford medial unicompartmental arthroplasty: a ten-year survival study. J Bone Joint Surg Br 1998; 80:983-9.
20. Tabor OB Jr, Tabor OB.Unicompartmental arthroplasty: a long-term follow-up study. J Arthroplasty 1998; 13:373-9.
21. Insall J, Dorr LD, Scott RD, Scott WN. Rationale of the Knee Society clinical rating system. Clin Orthop Relat Res 1989; (248):13-4.
22. Kennedy WR, White RP. Unicompartmental arthroplasty of the knee. Postoperative alignment and its influence on overall results. Clin Orthop Relat Res 1987; (221):278-85.
23. Perkins TR, Gunckle W. Unicompartmental knee arthroplasty: 3- to 10-year results in a community hospital setting. J Arthroplasty 2002; 17:293-7.
24. Lotke PA, Ecker ML. Influence of positioning of prosthesis in total knee replacement. J Bone Joint Surg Am 1977; 59:77-9.
25. Lootvoet L, Burton P, Himmer O, Pilot L, Ghosez JP. [A unicompartment knee prosthesis: the effect of the positioning of the tibial plate on the functional results] Acta Orthop Belg 1997; 63:94-101. French.
26. Berend ME, Ritter MA, Meding JB, et al. Tibial component failure mechanism in total knee arthroplasty, Clin Orthop Relat Res 2004; (428):26-34.
27. Moller JT, Weeth RE, Keller JO. Unicompartmental arthroplasty of the knee. Cadaver study of tibial component placement. Acta Orthop Scand 1985; 56:115-9.
28. 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; 84:2235-9.
29. 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. J Arthroplasty 2004; 19:296-301.
30. Voss F, Sheinkop MB, Galante JO, Barden RM, Rosenburg AG. Miller-Galante unicompartmental knee arthroplasty at 2- to 5-year follow-up evaluations. J Arthroplasty 1995; 10:764-71.
31. Hernigou P, Deschamps G. Alignment influences wear in the knee after medial unicompartmental arthroplasty. Clin Orthop Relat Res 2004; 423:161-5.
32. Cartier P, Sanouiller JL, Grelsamer RP. Unicompartmental knee arthroplasty surgery. 10-year minimum follow-up period. J Arthroplasty 1996; 11:782-8.