



## ■ SPECIALTY UPDATE

# Long-term results of compartmental arthroplasties of the knee

## LONG TERM RESULTS OF PARTIAL KNEE ARTHROPLASTY

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**Partial knee arthroplasty (PKA), either medial or lateral unicompartmental knee arthroplasty (UKA) or patellofemoral arthroplasty (PFA) are a good option in suitable patients and have the advantages of reduced operative trauma, preservation of both cruciate ligaments and bone stock, and restoration of normal kinematics within the knee joint. However, questions remain concerning long-term survival. The goal of this review article was to present the long-term results of medial and lateral UKA, PFA and combined compartmental arthroplasty for multicompartmental disease. Medium- and long-term studies suggest reasonable outcomes at ten years with survival greater than 95% in UKA performed for medial osteoarthritis or osteonecrosis, and similarly for lateral UKA, particularly when fixed-bearing implants are used. Disappointing long-term outcomes have been observed with the first generation of patellofemoral implants, as well as early Bi-Uni (ie, combined medial and lateral UKA) or Bicompartmental (combined UKA and PFA) implants due to design and fixation issues. Promising short- and med-term results with the newer generations of PFAs and bicompartmental arthroplasties will require long-term confirmation.**

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Partial knee arthroplasty (PKA) is an alternative to total knee arthroplasty (TKA) in patients with arthritis limited to one compartment of the knee. The benefits of PKA include the preservation of cruciate and collateral ligaments and bone stock, which in turn lead to the restoration of native knee kinematics.<sup>1-4</sup> Improvements in implant design, materials and surgical technique, coupled with a greater understanding of the indications for PKA, have led to marked improvements in functional outcomes and implant survival in the 40 years since PKA was introduced.<sup>5-7</sup> As such, PKA can now be considered to be a definitive solution for patients with end-stage osteoarthritis (OA) limited to one compartment. The goal of this review article is to present the long-term results of PKA techniques for single-compartment OA of the knee, including medial and lateral unicompartmental knee arthroplasty (UKA) and patellofemoral arthroplasty. Finally, the use of combined PKAs for multiple-compartment disease will be discussed.

### Medial UKA for degenerative arthritis

**Clinical outcomes.** There is now good evidence that medial UKA (of both fixed- and mobile-bearing design) provides good clinical outcomes into the medium term. A ten-year outcome study of 511 knees (in 402 patients) from

an independent centre using the mobile-bearing Oxford UKA (OUKA, ZimmerBiomet, Bridgend, United Kingdom) reported significant improvements in both functional scores and knee flexion.<sup>8</sup> The mean Knee Society score was 90.2 (72 to 100) at ten years compared with 51.5 points (26 to 68) pre-operatively, while mean active knee flexion increased from 105.5° (85° to 135°) to 130.9° (110° to 140°; both  $p < 0.0001$ ).

Argenson et al<sup>9</sup> reported the 20-year results of 160 medial metal-backed medial UKAs (Miller-Galante, ZimmerBiomet, Warsaw, Indiana) in 147 patients. At most recent follow-up, the 70 surviving patients had mean Knee Society score (KSS) knee and function scores of 91 points (50 to 100) and 88 points (45 to 100), respectively.<sup>9</sup> Mean active flexion increased from 119° (85° to 135°) pre-operatively to 127° (80° to 145°) at most recent follow-up. Similarly, a long-term series of 53 medial UKAs with an all-polyethylene tibial design reported mean KSS knee and function scores of 80.1 points (90 to 50) and 84.7 points (100 to 70), respectively at a mean follow-up of 14.7 years (4.2 to 15.3), with a mean active knee flexion of 120.6° (100° to 130°) at the same time point.<sup>10</sup>

There is some debate as to the relative functional outcomes of UKA and TKA for medial OA. At one year following surgery, Thienpont

**Table I.** Long-term studies of medial unicompartmental knee arthroplasty

Study	Implants	No. of knees	Duration of FU (yrs)	Revised (%) (any cause)
Argenson et al <sup>9</sup>	Miller-Galante	160	20	12
Price et al <sup>15</sup>	Oxford	114	15	8
Vorlat et al <sup>16</sup>	Oxford	149	10	19
Niinimäki et al <sup>17</sup>	Registry (all)	4713	15	30
O'Rourke et al <sup>18</sup>	Marmor	136	21	14
Manzotti et al <sup>10</sup>	UC-plus	53	10	9

FU, follow-up

et al<sup>11</sup> performed a retrospective comparison of 51 UKA patients with 50 TKA patients, reporting equivalent results using the forgotten joint score. In a study of 14 076 matched patients from the National Joint Registry for England and Wales, Liddle et al<sup>12</sup> reported that UKA provided superior short-term clinical outcomes than TKA (in terms of the Oxford knee score and the EQ5D, a quality of life score), higher satisfaction and lower complication rates, at six months following surgery. In their randomised controlled study, Sun et al<sup>13</sup> demonstrated that mobile-bearing UKA will result in lower complication rate, similar clinical outcomes when compared with a fixed-bearing TKA, however, the Oxford UKA revision rate in their series was 25%. However, Newman et al<sup>14</sup> showed that the better early results with UKR are maintained at 15 years with no greater failure rate.

**Implant survival.** Medium- and long-term studies suggest good ten-year survival of around 95% for UKA performed for medial OA in high-volume units.<sup>9,10,15-18</sup> (Table I). A series from the designing unit of the OUKA has reported 98% cumulative survival at ten years.<sup>19</sup> Price et al<sup>15</sup> reported 92% survival at 15 years in a series from an independent centre. In this series (as in other series of the Oxford UKA) a high rate of radiolucent lines was noted adjacent to the tibial component, although the significance of these lines is uncertain.

Argenson et al<sup>9</sup> reported 74% implant survival for the metal-backed, fixed bearing Miller-Galante UKA at 20 years. They reported that the two most common reasons for revision were progression of arthritis in the uninvolved compartments (65%) and polyethylene wear (25%). The mean time for revision to TKA or addition of a PFA was 13 years (three months to 21 years).

Similar results are reported for fixed-bearing devices with all-polyethylene tibial components.<sup>18</sup> However, these results may be device-dependent: a recent randomised study reported very poor survival for a UKA with an all-polythene tibial component compared with the metal-backed version of the same device.<sup>20</sup> The ten-year survival with the all polythene tibial component was 56.5% (95% confidence interval (CI) 31.9 to 75.2), compared with 93.8% (95% CI 77.3 to 98.4) in the metal-backed group ( $p < 0.001$ ), although the numbers at risk were low at ten years (seven and 16 for all-polythene and metal-backed components, respectively).

On the basis of the current literature, there is no consensus as to whether fixed- or mobile-bearing UKA gives better results in terms of survival or clinical outcome in the long term. While mobile-bearing implants have a higher rate of early bearing dislocation, polyethylene wear remains a complication of fixed-bearing devices in the longer term (although in patients with no evidence of infection or osteolysis, liner exchange may be a successful procedure in cases of polyethylene wear<sup>21</sup>). Parratte et al<sup>22</sup> reported a retrospective comparison of 79 fixed-bearing UKA with 77 knees with mobile-bearing UKA, reporting no significant difference in the rate of revision at a minimum of 15 years' follow-up (12 of 77 knees were revised in the mobile-bearing group, compared with ten of 79 in the fixed-bearing group,  $p = 0.44$ ). Likewise, Confalonieri et al<sup>23</sup> reported no difference in clinical outcomes between the two designs of UKA. Gleeson et al<sup>24</sup> reported a prospective non-randomised study of 91 patients undergoing either fixed (57 knees) or mobile-bearing (47) UKA. The rate of revision was higher in the mobile-bearing group, owing to a number of bearing dislocations, but this difference was not significant. Likewise, no significant difference was reported in either the Bristol nor the Oxford knee scores between the groups, albeit that a small difference in the pain component of the Bristol score was reported in favour of the fixed-bearing implant ( $p = 0.014$ ).

In contemporary practice, the discussion has focused on comparing the results of UKA and TKA. A study of 27-year data from the Finnish Joint Registry compared the survival of 4713 patients with UKA performed for primary OA (mean age of 64 years; mean follow-up of six years) with that of 83 511 patients who had undergone TKA (with a mean age of 70 years and a mean follow-up of six years).<sup>17</sup> Survival for UKA was 89% at five years, 81% at ten years, and 70% at 15 years, compared with 96%, 93%, and 88% respectively for TKA. UKA had inferior long-term survivorship compared with cemented TKA, adjusted for age and gender (hazard ratio 2.2;  $p < 0.001$ ).<sup>17</sup> The authors acknowledged that comparing survival directly by using arthroplasty register survival reports also may be inadequate because of differences in indications, implant designs, and patient demographics in patients having UKA and TKA. Despite these limitations, they concluded that while UKA has advantages, the risk of revision remains higher than expected with TKA.<sup>17</sup> In 2014, Liddle et al<sup>25</sup> reported

**Table II.** Long-term studies of lateral unicompartmental knee arthroplasty

Study	Implants	No. of knees	Duration of FU (yrs)	Revised (%) (any cause)
Argenson et al <sup>28</sup>	15 Marmor 20 Miller-Galante 4 Zuk 1 Alpina	40	16	16
Sah et al <sup>29</sup>	Brigham PFC Sigma Preservation	49	5	0
Lusting et al <sup>30</sup>	HLS evolution	54	10	2
Weston-Simons et al <sup>31</sup>	Oxford Domed	265	4	8 (failure rate including 1.5 dislocation)

FU, follow-up

the rates of adverse events for matched UKA or TKA patients extracted from England and Wales total joint registry, they concluded that the higher revision/re-operation rate of UKA should be balanced against a lower occurrence of complications, re-admission, and mortality. Based on their analysis, if 100 patients receiving TKA have received UKA instead, the result would be around one fewer death and three more re-operations in the first four years after surgery.

### Lateral UKA for degenerative arthritis

**Clinical outcomes.** Lateral UKA is far less common than medial UKA, and accounts for only around 1% of all knee arthroplasty procedures.<sup>26</sup> Smith et al<sup>27</sup> reported the results of 41 lateral PKAs at a minimum of five years' follow-up. Functional scores showed a significant improvement following surgery, with the benefit maintained to five years. The mean total KSS increased from 100 points (30 to 182) pre-operatively, to 159 (69 to 200) at five years ( $p < 0.001$ ). Mean OKS was increased from 20 points (5 to 45) to 37 points (9 to 48,  $p < 0.001$ ), and Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) scores increased from 36 points (15 to 53) to 22 points (12 to 48,  $p < 0.001$ ) over the same time period. Similarly, Argenson et al<sup>28</sup> reported favourable outcomes for lateral UKA, with mean KSS knee and function scores of 88 points (40 to 100) and 78 points (20 to 100), respectively at a mean follow-up of 12.6 years. Sah et al<sup>29</sup> reported that mean KSS knee and function scores improved from 39 and 45 points pre-operatively, to 89 and 80 points, respectively at a mean of 5.2 years. Finally, Lustig et al<sup>30</sup> reported KSS knee and function scores of 95 points (70 to 100) and 82 points (25 to 100), respectively, at ten years.

**Implant survival.** Argenson et al<sup>28</sup> published a series of 39 lateral UKAs and demonstrated reasonable clinical and radiographic results, with survival at ten and 16 years comparable with the survival obtained for medial UKA. Sah et al<sup>29</sup> reported a series of 49 knees at five years with no revisions after lateral UKA. Likewise, Lustig et al<sup>30</sup> reported a series of 54 lateral UKAs (52 patients, mean age 72 years) at a minimum of ten years' and a mean of 14 years' follow-up. A total of eight knees were lost to follow-up; in the

remainder they reported 94% survival at ten years and 91% at 15 years, with no revision for wear, infection or patellofemoral OA. Each of these studies used fixed-bearing implants and the most common indication for revision was progression of disease to the medial compartment (Table II).<sup>31</sup>

Given the amount of anteroposterior femoral translation observed in the lateral compartment, mobile-bearing lateral UKA has been associated with a high rate of bearing dislocation.<sup>3</sup> When the standard medial Oxford UKA has been used in the lateral compartment, bearing dislocation has been a serious issue with Gunther et al<sup>32</sup> reporting a 21% failure rate overall, and a 10% rate of bearing dislocation. This has led to the introduction of a new design of the Oxford UKA with a domed tibial component and a biconcave mobile-bearing. This has had a positive effect on outcomes with Weston-Simons et al<sup>31</sup> reporting that, at a mean follow-up of four years, 1.5% of knees had had a bearing dislocation, with an all-cause revision rate of 92% at eight years. With the same domed implant reported in their series of 58 lateral UKAs, Altuntas et al<sup>33</sup> reported no dislocation and 96.9% implant survivorship at maximal follow-up of three years.

### UKA for avascular necrosis

Avascular necrosis (AVN) of the knee classically includes two distinct entities: spontaneous or secondary osteonecrosis.<sup>34,35</sup> Spontaneous osteonecrosis occurs most often in patients older than 55, unilaterally, and in one compartment of the knee.<sup>34</sup> Secondary osteonecrosis can appear after corticosteroid therapy, renal and systemic diseases, or barotrauma, and occurs most often in younger patients with bilateral disease.<sup>34,35</sup> For both types of AVN, the natural evolution without treatment is arthritis.<sup>34,35</sup> As the rest of the knee is usually normal in unicompartmental osteonecrosis, medial or lateral UKA can be used in such cases.

Overall, favourable outcomes have been reported for UKA in the setting of AVN, both in terms of survival and functional outcome, albeit that most series have been small (Table III). Bruni et al<sup>36</sup> reported the results of 84 patients undergoing medial UKA for osteonecrosis, with a survival of 89% at ten years. The mean Knee Society score (KSS)

**Table III.** Survival studies of unicompartmental knee arthroplasty for medial osteonecrosis

Study	Implants	No. of knees	Duration of FU (yrs)	Revised (%) (any cause)
Parratte et al <sup>38</sup>	Miller-Galante	31	12	3.3
Bruni et al <sup>36</sup>	Preservation	84	10	11
Heyse et al <sup>37</sup>	Richard III	28	10	6.9

FU, follow-up

**Table IV.** Survival studies of patellofemoral arthroplasty

Study	Implants	No. of knees	Duration of FU (yrs)	Revised (%) (any cause)
De Winter <sup>47</sup>	1st Gen Richard II	26	11	19
Tauro <sup>48</sup>	1st Gen Lubinus	62	7.5	28
Nicol <sup>49</sup>	2nd Gen Avon	103	7.1	14
Odumenya <sup>50</sup>	2nd Gen Avon	50	5	0

FU, follow-up

was 87.1 (standard deviation (SD) 13.8) with a mean WOMAC score of 12 (SD 10.3) at latest follow-up (63 to 145).<sup>36</sup> Heyse et al<sup>37</sup> reported that the results of 28 knees with an overall survival was 93% at ten years. The mean KSS was 173 (SD 27) at latest follow-up, compared with 85 (SD 30) pre-operatively ( $p < 0.0001$ ), and the mean WOMAC score was 7.7 (SD 11.4) at the same time interval. Finally, Parratte et al<sup>38</sup> reported 31 patients with either primary or secondary osteonecrosis. Implant survival was at 96% at 12 years (with a single knee undergoing revision to TKA for aseptic loosening). At seven years, the mean KSS knee score was 95 points (75 to 100) and the mean function score was 88 (72 to 96).

**Patellofemoral arthroplasty.** Overall, the reported long-term results of patellofemoral arthroplasty (PFA) are inferior to those reported for medial and lateral UKA. However, compared with UKA, there has been much greater evolution in implant design over recent years, with first-generation resurfacing-type implants giving way to more modern devices which more closely resemble the anterior portion of a TKA. Most long-term results for PFA relate to earlier, now obsolete devices.<sup>39</sup>

**Outcomes of first-generation prostheses.** Overall, first-generation designs of PFA were associated with poor short-term survival, which has been attributed to design factors associated in particular with the deep trochlear groove in many such designs. Lonner et al<sup>40</sup> found that these highly-constrained designs tolerated patellar maltracking poorly, and were therefore unlikely to succeed in patients with poor pre-operative alignment without the use of re-alignment procedures during implantation.

A series of one such design, the Richards PFA (Richards prosthesis, Richards, Memphis, Tennessee), published in 1979, reported a 16% revision rate after two years of follow-up.<sup>41</sup> In the longer-term, survival rates of 75% and 69% have been reported at 11 and 20 years of follow-up, respectively,<sup>42,43</sup> with satisfactory results being achieved in 86% of cases after a period of 15 years to 21 years.

Similarly, another first-generation implant, the Lubinus PFA, had a high rate of early revisions.<sup>42,44-46</sup> The most common causes of failure were patellar instability (18%), stiffness (18%) and tibiofemoral OA progression (12%)<sup>46</sup> (Table IV).<sup>47-50</sup>

There are few studies which report long-term clinical outcomes following PFA, and most report on first-generation prostheses. De Winter et al<sup>47</sup> reported mean KSS of 90 points (65 to 100), in 21 Richards II PFAs at a mean follow-up of 11 years. Argenson et al<sup>51</sup> reported a series of 66 first-generation PFA implants (Autocentric; DePuy, Warsaw, Indiana) at a mean follow-up of 16 years. In these patients, the KSS functional score increased by 40 points from that pre-operatively, with a mean score of 81 points at latest follow-up. Likewise, reasonable results have been reported from the first-generation Lubinus PFA (Waldemar Link, Hamburg, Germany), with the mean Bristol knee score rising from 55 points (29 to 86) pre-operatively, to 81 (42 to 100) at latest follow-up, which was between five and ten years.<sup>48</sup>

**Outcomes of second-generation implants.** Results of newer implants are superior to earlier designs, but still do not reach the long-term levels of implant survival reported for UKA and TKA. Nicol et al<sup>49</sup> reported on 103 PFAs (Avon PFJR; Stryker Howmedica Osteonics, Mahwah, New Jersey) implanted in patients with a mean age of 68 years. Overall survival at seven years was 86%; unlike previous designs, the most common reason for revision was progression of arthritis to the tibiofemoral joint.

Ackroyd et al<sup>52</sup> reported 96% survival in 109 patients receiving the Avon PFA at five years with good functional results (with a mean OKS of 39, improved from 18 pre-operatively). Odumenya et al<sup>50</sup> reported 100% implant survival in 50 patients five years following implantation of the same prosthesis. One further multicentre study of 79 knees reported 84% good and excellent results and 90% of patients reported no knee pain during activities of daily living at three years following Avon PFA.<sup>48</sup>

**Table V.** Studies of combined compartmental arthroplasties

Study	Implants	No. of knees	Duration of FU	Revised (%) (any cause)
Parratte et al <sup>56</sup>	UKA:	84 Bi-UKA	17 yrs	22
	Zimmer condylar	71 UKA and PFA		44
	Alpina			
	Miller-Galante			
Palumbo et al <sup>57</sup>	PFA: Autocentric	36 UKA and PFA	21 mths	14
	Journey Deuce			31 clinical failure (persistent pain)

FU, follow-up; UKA, unicompartmental knee arthroplasty; PFA, patellofemoral arthroplasty

### Combined compartmental arthroplasties

PKAs can be used in combination when more than one compartment is affected by disease. This can either be a combination of a medial and lateral UKA (Bi-Uni) or a combination of UKA and PFA (bicompartamental arthroplasty, which can either be achieved with two implants or with one combined bicompartamental prosthesis). Combined compartmental arthroplasties can be an alternative to TKA with the advantages of preserving bone stock and restoring more normal kinematics.<sup>53-55</sup> Owing to these potential advantages over TKA, there is a renewed interest in combined compartmental implants.<sup>53,54</sup>

**Implant survival and functional outcomes following combined compartmental arthroplasties.** Parratte et al<sup>56</sup> reported a retrospective analysis of 177 knees (155 patients) receiving either bi-uni (100 knees) or bicompartamental arthroplasty (77 knees). At 17 years, implant survival was 78% in the bi-uni group and 54% in the bicompartamental group. Clinical outcomes, reported at a minimum of five, and a mean of 12 years, were more encouraging, with a mean KSS knee and function score of 88 (65 to 100) and 88 (58 to 100), respectively in the bi-uni group, up from 44 (25 to 64) and 42 (17 to 59); results were almost as good in the bicompartamental group, with the mean KSS knee score rising from 38 (14 to 65) to 84 (59 to 100) and the mean function score rising from 35 (10 to 57) to 79 (58 to 100). The authors explained the poor survival as being due to factors related to design and instrumentation of the prostheses used, and the use of cementless PFA (Table V).<sup>57</sup>

Data examining current implants are limited, however, short-term results with modern bi-uni or with bicompartamental arthroplasties using combinations of currently used implants appear promising.<sup>40,58,59</sup> One recent study, where 34 patients receiving bicompartamental arthroplasty were matched to similar patients receiving TKA demonstrated benefits in terms of knee flexion and forgotten knee score.<sup>58</sup> However, a second study of the same combination of implants, a randomised controlled trial of 48 patients at five years, demonstrated no benefit of bicompartamental arthroplasty over TKA in terms of functional scores, albeit with less blood loss reported in the bicompartamental group.<sup>60</sup>

The early results of a specially designed bicompartamental implant Journey Deuce (Smith & Nephew, Andover, Mas-

sachusetts) with a combined monobloc femoral component have been disappointing, and the implant has since been recalled because of its high failure rate.<sup>57,61</sup> In terms of functional results, a study comparing 50 bicompartamental arthroplasties with 50 TKAs demonstrated no difference in terms of KSS or OKS at two years.<sup>62</sup>

Modern combined compartmental arthroplasty is still in its infancy, but shows promise. From the early studies of this technique, it seems important to select patients with intact cruciate ligaments and only moderate frontal and sagittal deformities. We recommend the use of fixed-bearing implants in the medial compartment, and use of separate implants for the bi-compartmental arthroplasties with a cemented second generation of patellofemoral implant.<sup>58</sup>

Medial and lateral UKAs have demonstrated good mid- to long-term implant survival with excellent functional outcomes when performed in centres with expertise in performing such cases. There appears to be little difference on the basis of current data between fixed- and mobile-bearing devices in the medial compartment, but we prefer fixed-bearings in the lateral compartment as there is a significant incidence of bearing dislocation with mobile bearings. UKA offers tempting advantages regarding morbidity and function, but has a higher risk of revision in the longer term; therefore, it may be that the choice of TKA or UKA represents the choice between superior revision rates and superior functional outcomes. Disappointing long-term outcomes have been observed with the first generation of PFAs, and in early series of combined compartmental arthroplasties owing to factors related to implant design and fixation. Promising short- and mid-term results with the new generation of PFAs and bicompartamental arthroplasties should now be confirmed at longer follow-up.

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