Title: Five-year experience of cementless Oxford unicompartmental knee replacement

Abstract

Purpose: Cementless unicompartmental knee replacement (UKR) was introduced to address some of the problems that can occur following cemented UKR. The aim of this study was to report the five year experience of the first 512 medial cementless Oxford UKR implanted by two surgeons for the recommended indications.

Methods: The first consecutive 512 cementless Phase 3 Oxford cemented UKRs implanted by two surgeons for the recommended indications between June 2004 and October 2013 were prospectively identified and followed up independently. All the procedures were carried out through a minimally invasive approach without eversion or dislocation of the patella. Patients were assessed clinically preoperatively and at one, two, five, seven and ten years after surgery with functional outcome scores and radiographs.

Results: There were 8 reoperations of which 6 were revisions giving a 5 year survival of 98% (95% CI 94 - 100%). At a mean follow-up of 3.4 years (1.0 to 10.2) the mean OKS was 43 (SD 7), AKSS (objective) was 81 (SD 13) and AKSS (functional) was 86 (SD 17). The first 120 cases had a minimum follow up of five years (mean 5.9; range 5 - 10.2). In these patients the mean OKS was 41 (SD 8), AKSS (objective) was 81 (SD 14) and AKSS (functional) was 82 (SD 18). There were no femoral radiolucencies, and no complete tibial radiolucencies. 11% of tibial components had partial radiolucent lines; the remaining 89% had no radiolucencies.

Conclusion: The clinical results are as good as or better than those previously reported for cemented fixation. The radiographic results are better with secure bony attachment to the implants in every case.

Level of Evidence: Level IV

Keywords: unicompartmental knee replacement, cementless fixation, implant survival, functional outcome
**Introduction**

Cementless fixation is a viable alternative to cemented unicompartmental knee replacement (UKR) for treating symptomatic anteromedial osteoarthritis [2,12,15,16,26,23,28]. Cementless fixation has advantages including avoidance of cementing errors (inadequate cementation, loose cement fragments, impingement due to excess cement) and faster surgical time. There is the potential advantage of reducing the incidence of peri-prosthetic radiolucent lines (physiological radiolucencies) which are common around cemented tibial components. Even if clinically unimportant, they often lead to misdiagnosis of aseptic loosening and unnecessary revisions especially by inexperienced surgeons. This may in part explain the higher revision rate in the Joint Registries (NJR) than specialist centres [19,31,3]. The main potential disadvantage of cementless fixation is that it may have a higher loosening rate as was found with TKR [4].

Two randomised controlled trials have compared the quality of fixation of cementless and cemented Oxford UKR (OUKR) [14,23] on a limited number of patients (n = 62, n = 43). In one component migration was assessed using radio-stereometric analysis (RSA). Although the cementless had more migration in the first year, the migration in the second year was the same suggesting that the fixation was equally good. In both studies the incidence of radiolucencies was lower with cementless fixation. These studies were too small to reliably assess outcome scores, complications or contraindications. A multicentre study of 1000 cases was therefore undertaken [16]. This demonstrated an acceptable level of complications, satisfactory outcome scores and no contraindications beyond those for cemented UKR. The study had a mean follow-up of two years and a radiological assessment at one year. Mid-term data is therefore needed. This is particularly important as the hydroxyapatite used for fixation may dissolve over time [30].

This prospective study, which is the largest series of cementless minimally invasive UKRs with mid-term survival data, describes the outcome of the first 512 cementless Oxford Phase 3 medial UKR implanted using a minimally invasive surgical approach for the recommended indications by two designer surgeons and followed up independently, with the aim to determine the complication rate, the clinical outcome and the mid-term survival. The results of this study will provide evidence about the use of the cementless OUKR in clinical practice.
Materials and Methods

Since June 2004, the cementless Phase 3 OUKR performed by the designer surgeons (DWM & CAFD) have been followed up prospectively. All the clinical assessments are performed in a dedicated clinic by a research physiotherapist who is independent of the surgical and clinical teams involved in the care of the patients and not aware of the specific aim of the study to reduce the risk of bias. The end of recruitment for this study was 1 October 2013. During this time frame 579 cementless medial UKRs were performed in 520 patients with a mean age at the time of the operation of 65.1 years (range: 35 to 94, SD 10.3). There were 299 men and 221 women. There were 521 unilateral, 2 simultaneous bilateral and 56 staged bilateral procedures. Of the 579 procedures, 512 knees included in this study fulfilled the recommended indications for the cemented OUKR (505 for end-stage anteromedial osteoarthritis and 7 for spontaneous osteonecrosis) [10,25,24] and 67 knees were implanted for extended indications (24 in combination with anterior cruciate ligament (ACL) reconstruction, 22 in patients without a functionally intact ACL, 2 in patients with previous high tibial osteotomy (HTO), and 19 UKR for other reasons, as specified in Table 1). These 67 knees were excluded from the current analysis. However, their results are presented separately for completeness.

All the procedures were carried out through a minimally invasive approach without eversion or dislocation of the patella [10]. All procedures were performed using a cementless fixation. The cementless OUKR implant is similar to the widely used cemented OUKR but has modifications to facilitate cementless fixation [23]. The cement pockets on both components are filled with porous titanium and the surfaces that are in contact with bone are coated with calcium hydroxyapatite (HA). The vertical tibial wall is not considered weight bearing and is not coated with titanium, although it is coated with hydroxyapatite. The porous plasma spray coating produced upon the cementless Oxford partial knee implants are produced by the deposition of Ti-6Al-4V alloy powder upon the surface of the components, the thickness of this coating complies with the requirements of the FDA and has a total coating thickness of between 500 and 1,500 microns. The femoral component extends a further 17° anteriorly to allow implantation in a flexed position, and has two HA-coated cylindrical pegs for press-fit fixation and to confer rotational stability. The femoral component is implanted in 5° to 10° of flexion and the slot for the tibial keel is narrower than the cemented in order to provide a good initial press-fit. Care was taken to ensure that accurate ligament balance was achieved and that the bearing did not impinge on retained bone or cement. Patients were allowed to mobilise within pain limits and fully weight-bear as tolerated. They were treated with a uniform rehabilitation protocol including muscular strengthening and progressive ROM exercises. All patients received a general anaesthetic with a short-acting femoral block and
local anaesthetic intra-articular infiltration. No pain pumps were used. Patients were given low dose aspirin or low molecular weight heparin and graduated compression stockings for first two weeks after surgery for thromboembolic prophylaxis.

Patients were assessed clinically preoperatively and at one, two, five, seven and ten years after surgery. The clinical outcome was assessed using the Oxford knee score (OKS), a validated patient-based questionnaire [18]. We used this score with a minimum of 0 (worst outcome) and maximum of 48 (best outcome). The American Knee Society Score (AKSS), both functional and objective, was also used [13]. Each patient’s level of activity was recorded with the Tegner score [32]. If for any reason (social, geographic or medical) the patients were unable to attend for follow-up, they were contacted by telephone or by post and relevant clinical information obtained [1]. For patients who had died, information was gathered from hospital and general practitioners’ records to establish whether the patient had undergone any further surgery on the knee under investigation. Operative data was collected using a standard form, which recorded surgical findings including the status of the ACL and the status of the cartilage in the involved as well as the retained compartments. Revision was defined as inserting a new component in the knee. Using this definition of revision as failure a life table survival analysis was undertaken.

Aligned post-operative radiographs were obtained either using an image intensifier or a digital radiographic system. The radiographic beam for the AP radiographs was aligned parallel with the tibial component and for the lateral radiographs was perpendicular to the femoral component as previously described [11]. All the five year follow-up radiographs were assessed and compared with the postoperative radiographs, looking for progression of osteoarthritis in the lateral compartment and patella-femoral joint, the presence and extent of radiolucency and evidence of component subsidence. All the assessments were performed by two independent observers (SC, SP). For descriptive purposes, the interface under the tibial implant was divided into three areas: zone A medial to the keel, zone B surrounding the keel and zone C lateral to the keel. The interface lateral to the vertical wall was not studied, as it is non-weight-bearing. The presence of radiolucencies was classified as absent, partial or complete for each area of the interface under the tibial component. When present, the maximum thickness of radiolucencies was measured using the femoral implant to calibrate the images.

This study was approved by the local ethics committee chair person (Oxford Research Ethics Committee C) who confirmed that the clinical and radiological follow up of these patients formed part of routine assessment and therefore does not need formal ethical approval. Consent was taken from all patients for involvement in this study including consent to use data from medical records and radiographs.
**Statistical Analysis**

Mann-Whitney U tests were performed to compare the pre-operative and post-operative (most recent) scores for OKS, AKSS, Tegner scores and range of movement. Statistical significance was set at $p < 0.05$. Pearson’s correlation test was performed to measure the intra-observer variability. All analyses were carried out using SPSS version 16.0 for Windows (SPSS Inc., Chicago, USA).

**Results**

**Results of all patients with recommended indications**

One patient was lost at follow-up after 5 years, five patients died, none as a result of their surgery, and three patients were dropped from the study due to associated medical problems however none of these have had a revision.

There were 8 re-operations (8 patients, 1.6%) with six of these cases considered revisions as they needed either exchange of an existing component or addition of a new component (Table 2). The most common reason for revision was progression of arthritis in the lateral compartment, (three knees, 0.6%), followed by bearing dislocation (two knees, 0.4%) and in one case a patella-femoral replacement was implanted. Of the three knees revised for lateral compartment arthritis two were treated with lateral UKR and one converted to a TKR. In both patients with bearing dislocation a new bearing was inserted. We do not have good information about the case that had a patella-femoral replacement (PFR) as this was performed at another hospital. This patient had sequential bilateral OUKR, at operation on one side had much more severe damage to the PFJ than the other. The side with least PFJ damage was the one that had the PFJR. The PFJR was implanted at 2 years post UKR, when the skyline radiograph showed good preservation of the PFJ joint space (Figure 1). In this situation, if the PFJ was considered to be symptomatic we would have done an arthroscopy. There were no revisions for component loosening and there were no peri-prosthetic fractures. Two cases needed washout of the knee for superficial infection without exchange or addition of another component.

Table 3 shows the life table survival with failure being revision defined as insertion of a new component. The survival at 5 years was 97.6% (95% CI 93.6 - 100%).

496 out of 512 knees were assessed within the past one year, the remainder, as described above. The mean follow up was 3.4 years (SD 1.7, range 1.0 to 10.2). All functional scores improved significantly from baseline. Table 4. 75% had an excellent clinical outcome according to the AKSS criteria (80 to 100), 13% had a good outcome (70 to 79), 6% had a
Clinical results of patients with recommended indications and minimum follow-up of five years

The first 120 cases had a minimum follow-up of five years and the mean follow-up was 5.9 years (SD 1.4, range 5 - 10.2). The functional outcomes are outlined in Table 4 with 80% of the patients with good or excellent outcome according to the AKSS criteria.

Radiographic analysis

Out of 120 knees with surgery performed at least 5 years prior, one had undergone revision surgery for progression of OA in the lateral compartment and 13 patients (14 knees) could not attend radiographic assessment due to medical/geographical or social reasons. Out of the remaining 106 knees, none showed any evidence of loosening of either the femoral or tibial component. There was no significant progression of the arthritis in the retained compartments and none of the cases showed presence of complete physiological or pathological radiolucencies. Partial radiolucent lines were seen in 12 knees (11%) (Figure 2). The intra- and inter-observer reliability was > 0.9. The mean thickness of radiolucencies in these patients was 1.3 mm (range 0.5-2.3, SD = 0.5). Figure 3 shows the thickest radiolucency.

When available, the postoperative, 2-years and 5-years follow-up radiographies were compared. This was possible in 93 cases. In nine cases small RLs visible in postoperative radiographs underneath the tibial component laterally to the keel, disappeared in subsequent follow-up radiographs. These findings are likely to be a manifestation of seating of the component in the first months after surgery, as previously reported in RSA studies on cementless OU KRs [14]. One tibial component had a valgus subsidence of 5.2° at 2 years. This patient also had a radiolucency in zone C, but no radiolucencies in the other zones underneath the tibial component. The clinical results were satisfactory (OKS = 40, AKSS functional = 90) and the patient had no further complications.

Clinical results of patient outside recommended indications

Sixty seven knees were treated with cementless OUKR in situations that did not satisfy the recommended indications. Patient demographics and indications are specified in table 1. No
patients died as a result of their surgery. One patient died because of unrelated causes. One patient dropped out of the study due to severe medical problems. The mean follow up for the remaining was 3.4 years (SD = 1.6, range 0.9 to 8.3). There were no other major medical complications.

There were one revision for bearing dislocation in a patient with severe ligament laxity, one bearing dislocation treated by closed reduction, one case of postoperative stiffness treated by manipulation under anaesthesia and two arthroscopies for persistent pain. The survival was 98.3% (CI 95%: 92.3-100) at five years with failure defined as insertion of a new component. The functional outcomes are outlined in Table 4 with 78% having good or excellent clinical outcome according to the AKSS criteria.

**Discussion**

The most important finding if this study is that it demonstrates that cementless UKR can be safely used in all patients with antero-medial osteoarthritis who meet the indication for UKR. This is the first prospective study of a large cohort of consecutive patients who had undergone cementless Oxford UKR for the recommended indications. This study found good clinical outcomes and an implant survival of 98% at five years.

In the cohort patients with minimum follow up of 5 years, none of those with an available radiograph (n=106) showed evidence of complete radiolucencies or pathological radiolucencies. There was no evidence of progression of radiolucency after the first year so it is unlikely that there will be loosening in the long term [14]. 11% of the knees had partial tibial radiolucencies and the remaining 89% had no radiolucencies. Most radiolucencies were hardly visible (Figure 2). The thickest radiolucency was 2.3 mm in zone C (Figure 3). This is unlikely to be of any concern as there was secure fixation around and medial to the keel (zones A&B) and the patient had a good clinical outcome (OKS 40).

None of the patients in the series underwent revision for loosening which is one of the commonest causes of failure in the National Joint Registers [19]. If cementless fixation decreased the incidence of these problems the results of UKR in the national joint registers should improve substantially. It is likely that the dramatic decrease in incidence of complete radiolucent lines from about one third in cemented components to zero in cementless contributes to this. Although complete physiological radiolucencies are not indicative of loosening or a source of pain [11], inexperienced surgeons often think they are. Therefore if a patient does have pain and an associated radiolucency they may will be revised and the cause of revision will be reported as unexplained pain or loosening. Pain during the first postoperative year is not uncommon and tends to spontaneous regression in the vast
majority of cases. With cementless fixation as complete radiolucent lines are very rare or absent the number of unnecessary revisions should significantly reduce.

Many surgeons have reservations about use of cementless UKR, particularly in the light of poor results achieved with cementless TKR [4,6,7]. One concern is that patients who are old or have history of osteoporosis or poor bone quality on DEXA, should not be offered cementless fixation because of fear of implant subsidence and loosening [27,21]. In the current series, cementless fixation was used in all comers and no attempt was made to establish whether the patients suffered from osteoporosis with a third of patients (34%) aged 70 years or older and 8% 80 years or older at the time of surgery. In neither of these subgroups were there cases of implant subsidence or loosening, confirming that use of cementless Oxford is safe in the elderly. Whilst this may seem counterintuitive there is a logical explanation. Due to the mobile bearing design the load at the bone-implant interfaces is almost entirely compressive, with tibial loading within the central third thus avoiding rocking of the implant and associated tensile stresses.

Additionally surgeons have reservations about the use of cementless fixation for spontaneous osteonecrosis (SONK). Of the seven cases of SONK in this series none were revised or had evidence of loosening or subsidence. Although the numbers are too small to draw firm conclusions the results are encouraging. In SONK the lesion is usually central on the femoral condyle with the remaining bone being relatively normal. As such the anterior part of the component and small peg gains can adequate fixation in front to the lesion with the posterior part behind the lesion and end of the peg gaining fixation deep to the lesion. We believe that the unique features of the OUKR, including the fully congruent mobile bearing, the two-pegged spherical femoral component and the flat tibial surface added with porous titanium and HA-coating play a synergistic role that makes this implant really suitable for cementless fixation and justifies the good results obtained so far in anteromedial OA and SONK.

There is also a concern about peri-prosthetic tibial fracture. A cadaver study has shown that the load to fracture with a cementless OUKR is less than with a cemented OUKR [29] suggesting that the incidence of fracture should be higher with the cementless. Although this has been the case with some surgeons; we have not experienced a single peri-prosthetic fracture in this large cohort. This is possibly because of experience of the surgeons in this series who are familiar with the implant design and principles of surgical technique which have not changed. It is difficult to ascertain the learning curve for the designer surgeons. For sake of completeness all the cases have been included and no significant difference was detected in function outcome or survival when comparing the first 20 cases to last 20 cases in this series (data not presented). The key steps to minimise the risk of fracture are:
lateralising the vertical tibial cut to ensure maximum coverage of the tibia; avoiding deep
typical cuts; avoiding damage to the posterior cortex when preparing the tibia, and using a
small (toffee) hammer to seat the components. The use of the keel-cut saw and the
microplasty instrumentation (with avoidance of tibial recuts) are also very important.

Other studies have reported the results of other modern cementless unicompartmental
implants such as the HA-coated Unix and the Alpina. Epinette et al. in 2008 published the
results of the HA-coated Unix (an HA-coated implant with a horizontal fin inserted under the
tibial spine and screws for tibial component fixation) on 114 patients with a minimum follow-
up of 5 years, reporting no failures for loosening of components [8]. More recently, Hall et al.
reported a survival of 88% at 12 years on 85 patients with aseptic loosening set as the end
point [12]. LeCuire et al. reported a survival of 88% of the Alpina cementless
unicompartmental replacement at 13 years on 101 patients [15]. Unfortunately the
heterogeneity of outcome measures, length of follow-up, number of patients and design and
surgical technique do not permit a proper comparison of results.

Over the past decade, we have used the cementless Oxford in patients outside
recommended indications. In the current study, a small but significant proportion fall in this
subgroup (67/579 = 11%). It is interesting to note that in this subgroup neither the survival
nor the functional outcome is significantly worse than the main group. This is contrary to our
previous observation with the cemented implant [24]. The difference in results may be
because the length of follow up of the cemented cohort was much longer. We therefore
continue to recommend adherence to the recommended indications and await the longer
term results in this subgroup.

The main limitation of the study is that it is the results of the two designer surgeons so
potentially is not generally applicable. It should, however, indicate the best possible results.
Furthermore if other surgeons use the same indications and techniques then they should
achieve the same good results. There is evidence from the cemented experience that this
does actually happen. We are aware of 8 published or presented series of cemented OUKR
that have reported ten year survival rates [5,9,17,33]. In these series, which included about
6000 cases, the ten year survival was similar to that achieved in the designers series which
included 10 year survival published in 2011 [24]. Interestingly the results of first 512
cementless (described in this paper) are superior to those reported for the first 688
cemented OXs described in the designer surgeons published in 2006 that had similar
follow-up [22]. (For cementless and cemented respectively mean OKS 41 (SD 8) vs 39 (SD
9), AKSS (F) 82 (SD 19) vs 79 (SD 21), AKSS (O) 81 (SD 14) v 91 (SD 11), Tegner activity
score 3.0 (SD 1.0) vs 2.6 (SD 0.9)). It could be argued that this may be a result of the
improvement in technique with time rather than the change in fixation. It is therefore fair to
conclude that in experienced surgeons' hands out to five years the clinical results of the cementless OUKR are at least as good as the cemented with a significantly lower incidence of radiolucencies.

Finally, it is interesting to notice that according to data from the New Zealand Joint Registry the yearly revision rate of the cementless OUKR resulted lower compared to the cemented version (0.72 vs 1.37) [20]. Moreover, the cementless OUKR has a significantly lower revision rate than the overall mean of 1.27 of all cementless unicompartmental implants. However, these results could be influenced by many variables and still need to be studied to draw definitive conclusions.

The clinical relevance of this study is that it provides mid-term evidence that supports the use of the cementless OUKR in clinical practice. Furthermore the radiographic results, which demonstrated secure fixation in all cases, and are better than those seen with the cemented design in the mid-term, are promising with regards to the long term results.

Conclusion

This study demonstrates good functional outcomes and implant survival in knees treated with cementless OUKR for the recommended indications at five years. The clinical results of the first 512 knees treated with cementless OUKR are at least as good as those achieved with cemented fixation. The radiographic results are better with significantly lower incidence of radiolucent lines. This study provides short to medium term evidence to support the use of cementless OUKR.

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**Table 2:** Details of patients requiring revision

<table>
<thead>
<tr>
<th>Patient</th>
<th>Gender</th>
<th>Age (y)</th>
<th>F-up (y)</th>
<th>Side</th>
<th>Cause of failure</th>
<th>Revision surgery</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>F</td>
<td>66</td>
<td>1.8</td>
<td>Right</td>
<td>Bearing dislocation</td>
<td>Open reduction and bearing exchange</td>
</tr>
<tr>
<td>2</td>
<td>F</td>
<td>77</td>
<td>2.3</td>
<td>Right</td>
<td>Bearing dislocation (when playing badminton)</td>
<td>Open reduction and bearing exchange</td>
</tr>
<tr>
<td>3</td>
<td>M</td>
<td>77</td>
<td>2.1</td>
<td>Right</td>
<td>PFJ OA</td>
<td>PFJ Replacement</td>
</tr>
<tr>
<td>4</td>
<td>M</td>
<td>67</td>
<td>4.2</td>
<td>Left</td>
<td>Progression of OA in lateral compartment</td>
<td>Revised to bicompartamental UKR</td>
</tr>
<tr>
<td>5</td>
<td>M</td>
<td>67</td>
<td>6.9</td>
<td>Left</td>
<td>Progression of OA in lateral compartment</td>
<td>Revised to bicompartamental UKR</td>
</tr>
<tr>
<td>6</td>
<td>F</td>
<td>76</td>
<td>4.0</td>
<td>Right</td>
<td>Progression of OA in lateral compartment and PFJ</td>
<td>Revised to TKR</td>
</tr>
</tbody>
</table>
**Table 3:** Life table with the point of failure defined as revision of the prosthesis or any component part or implant of lateral UKR for knees treated for recommended indications.

<table>
<thead>
<tr>
<th>Follow Up (Yrs)</th>
<th>Number at start</th>
<th>Revised</th>
<th>Withdrawn</th>
<th>Lost to FU</th>
<th>Dead</th>
<th>At Risk</th>
<th>Annual Failure</th>
<th>Annual Success</th>
<th>Survival</th>
<th>95% CI</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 1</td>
<td>512</td>
<td>0</td>
<td>8</td>
<td>0</td>
<td>1</td>
<td>508</td>
<td>0.000</td>
<td>1.000</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>1 to 2</td>
<td>504</td>
<td>1</td>
<td>111</td>
<td>0</td>
<td>0</td>
<td>449</td>
<td>0.002</td>
<td>0.998</td>
<td>99.8</td>
<td>99.3</td>
<td>100</td>
</tr>
<tr>
<td>2 to 3</td>
<td>392</td>
<td>2</td>
<td>107</td>
<td>0</td>
<td>2</td>
<td>339</td>
<td>0.006</td>
<td>0.994</td>
<td>99.2</td>
<td>98.2</td>
<td>100</td>
</tr>
<tr>
<td>3 to 4</td>
<td>283</td>
<td>0</td>
<td>118</td>
<td>0</td>
<td>1</td>
<td>224</td>
<td>0.000</td>
<td>1.000</td>
<td>99.2</td>
<td>98.0</td>
<td>100</td>
</tr>
<tr>
<td>4 to 5</td>
<td>165</td>
<td>2</td>
<td>84</td>
<td>0</td>
<td>1</td>
<td>123</td>
<td>0.016</td>
<td>0.984</td>
<td>97.6</td>
<td>94.9</td>
<td>100</td>
</tr>
<tr>
<td>5 to 6</td>
<td>79</td>
<td>0</td>
<td>45</td>
<td>1</td>
<td>0</td>
<td>57</td>
<td>0.000</td>
<td>1.000</td>
<td>97.6</td>
<td>93.6</td>
<td>100</td>
</tr>
<tr>
<td>6 to 7</td>
<td>34</td>
<td>1</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>29</td>
<td>0.034</td>
<td>0.966</td>
<td>94.2</td>
<td>86.0</td>
<td>100</td>
</tr>
<tr>
<td>7 to 8</td>
<td>23</td>
<td>0</td>
<td>12</td>
<td>0</td>
<td>0</td>
<td>17</td>
<td>0.000</td>
<td>1.000</td>
<td>94.2</td>
<td>83.4</td>
<td>100</td>
</tr>
<tr>
<td>8 to 9</td>
<td>11</td>
<td>0</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>9</td>
<td>0.000</td>
<td>1.000</td>
<td>94.2</td>
<td>79.0</td>
<td>100</td>
</tr>
</tbody>
</table>
### Table 4: Functional Outcomes

<table>
<thead>
<tr>
<th></th>
<th>Pre-operative Mean (SD)</th>
<th>Most Recent Follow Up Mean (SD)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>OKS</strong></td>
<td>27 (9)</td>
<td>43 (7)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td><strong>AKSS – Objective</strong></td>
<td>52 (20)</td>
<td>81 (13)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td><strong>AKSS – Objective</strong> without deductions for alignment*</td>
<td></td>
<td>92 (12)</td>
<td></td>
</tr>
<tr>
<td><strong>AKSS – Functional</strong></td>
<td>71 (17)</td>
<td>86 (16)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td><strong>Tegner Activity Score</strong>**</td>
<td>3 (1 - 7)</td>
<td>3 (1 - 8)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td><strong>Knee Flexion (degrees)</strong></td>
<td>118 (10)</td>
<td>123 (6)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

**Results of all patients with recommended indications**

- **OKS**: 27 (9) vs. 43 (7), p < 0.001
- **AKSS – Objective**: 52 (20) vs. 81 (13), p < 0.001
- **AKSS – Objective without deductions for alignment**: 92 (12)
- **AKSS – Functional**: 71 (17) vs. 86 (16), p < 0.001
- **Tegner Activity Score**: 3 (1 - 7) vs. 3 (1 - 8), p < 0.001
- **Knee Flexion (degrees)**: 118 (10) vs. 123 (6), p < 0.001

**Results of all patients with recommended indications with a minimum 5 year follow up**

- **OKS**: 25 (9) vs. 41 (8), p < 0.001
- **AKSS – Objective**: 45 (15) vs. 81 (14), p < 0.001
- **AKSS – Functional**: 67 (16) vs. 82 (19), p < 0.001
- **Tegner Activity Score**: 2 (1 - 4) vs. 3 (1 - 7), p < 0.001

**Results of all patients outside of recommended indications**

- **OKS**: 27 (8) vs. 40 (10), p < 0.001
- **AKSS – Objective**: 48 (21) vs. 76 (22), p < 0.001
- **AKSS – Functional**: 72 (20) vs. 84 (18), p < 0.001
- **Tegner Activity Score**: 3 (1 - 5) vs. 3 (1 - 8), p < 0.001

*In the AKSS (objective) there are deductions for non-neutral alignment. These are not appropriate for UKR as the aim is to restore pre-disease not neutral alignment [22].

** Median (range)
Table 1: Patients not included in the study as they did not have the recommended indications

<table>
<thead>
<tr>
<th>Reason of exclusion</th>
<th>Number</th>
<th>Mean Age (y) and (range)</th>
<th>Mean Follow-up (y) and (range)</th>
<th>Comments/complications (further surgeries)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simultaneous ACLR</td>
<td>24</td>
<td>55.2 (41-71)</td>
<td>2.8 (1.1-6.2)</td>
<td>Persistent pain: 1 case (arthroscopy – no cause identified), Stiffness: 1 case (manipulation under anaesthesia)</td>
</tr>
<tr>
<td>ACL deficient</td>
<td>22</td>
<td>66.7 (47-82)</td>
<td>3.44 (0.9-6.5)</td>
<td></td>
</tr>
<tr>
<td>Cartilage loss in lateral compartment (PTCL/FTCL)</td>
<td>4 (2 PTCL, 2 FTCL)</td>
<td>72.5 (55-80)</td>
<td>3.66 (2.0-5.2)</td>
<td></td>
</tr>
<tr>
<td>PTCL medial compartment</td>
<td>3</td>
<td>67 (62-76)</td>
<td>4.25 (3.5-5.0)</td>
<td></td>
</tr>
<tr>
<td>Previous high tibial osteotomy</td>
<td>2</td>
<td>62.5 (59-66)</td>
<td>4.48 (4.1-4.9)</td>
<td></td>
</tr>
<tr>
<td>Previous tibial tubercle transposition</td>
<td>2</td>
<td>45.5 (45-46)</td>
<td>7.48 (6.6-8.3)</td>
<td>Persistent pain: 1 case (arthroscopy - disease progression in retained compartment)</td>
</tr>
<tr>
<td>PCL deficient</td>
<td>2</td>
<td>52.5 (44-61)</td>
<td>4.89 (4.7-5.1)</td>
<td>Bearing dislocation: 1 case (closed reduction)</td>
</tr>
<tr>
<td>Rheumatoid arthritis</td>
<td>1</td>
<td>52</td>
<td>2.93</td>
<td></td>
</tr>
<tr>
<td>Previous patella fracture</td>
<td>1</td>
<td>61</td>
<td>3.30</td>
<td></td>
</tr>
<tr>
<td>Large tibial cyst grafted</td>
<td>1</td>
<td>67</td>
<td>4.04</td>
<td></td>
</tr>
<tr>
<td>Previous OCD</td>
<td>1</td>
<td>52</td>
<td>4.15</td>
<td></td>
</tr>
<tr>
<td>Patient is a below knee amputee</td>
<td>1</td>
<td>82</td>
<td>0.98</td>
<td>Dropped from study</td>
</tr>
<tr>
<td>Very lax ligaments</td>
<td>1</td>
<td>43</td>
<td>1.46</td>
<td>Bearing dislocation: 1 case (bearing exchange) followed by further dislocation and lateral compartment OA (revision to TKR)</td>
</tr>
<tr>
<td>Lateral facet PFJ bone loss</td>
<td>1</td>
<td>59</td>
<td>1.62</td>
<td></td>
</tr>
<tr>
<td>Anterior tibial bone graft</td>
<td>1</td>
<td>81</td>
<td>2.42</td>
<td>Deceased</td>
</tr>
</tbody>
</table>