The fate of augments to treat type-2 bone defects in revision knee arthroplasty

We report the five- to ten year results of Anderson Orthopaedic Research Institute type-2 bone defects treated with modular metal augments in revision knee surgery.

A total of 102 revision knee arthroplasties in patients with type-2 defects treated with augments and stems were prospectively studied. Seven patients (seven knees) had incomplete follow-up and 15 patients (16 knees) died with the arthroplasty in situ. The mean follow-up of the 79 remaining knees was 7 ± 2 years (5 to 11). The presence of non-progressive radiolucent lines around the augment in 14% of knees was not associated with poorer knee scores, the range of movement, survival of the component or the type of insert which was used (p > 0.05). The survival of the components was 92 ± 0.03% at 11 years (95% CI, 10.3 to 11.2).

We recommend the use of modular augmentation devices to treat type-2 defects in revision knee surgery.

Patients and Methods

Between 1991 and 1996, 135 revision TKR procedures were conducted by the surgeon undertaking the operation as having AORI type-2 bone defects (Fig. 1). Bulk allograft or impaction grafting and cement were used in 33 knees. The remaining 98 patients (102 knees) were revised using stemmed components with augmentation devices to treat bony defects. There were 44 men and 54 women with a mean age of 69 ± 9 years (41 to 87). There were 53 right and 49 left knees. The mean Body Mass Index of the patients at operation was 30 ± 6 kg/m² (17 to 42). The underlying pathology was primary osteoarthritis for 88 knees, rheumatoid arthritis for ten and post-traumatic osteoarthritis for four. Revision was for wear and osteolysis in 28 knees, for sepsis in 26, for aseptic loosening in 21, for patellofemoral complications in 12 (two for unstable patellae and ten for worn polyethylene components), for instability in 11, for periprosthetic fracture in two and for pain of...
unknown origin in two. There were 99 revisions of a primary TKR and three revisions of a unicompartmental prosthesis. The distribution of bony defects encountered is shown in Table II. We revised 68 knees using the Co-ordinate knee system (DePuy, Warsaw, Indiana) and 34 using the Genesis I system (Smith & Nephew, Memphis, Tennessee).

The Co-ordinate system has a 6 to 10 mm thick cobalt-chrome femoral component, depending on size, which accepts 4 and 8 mm thick cobalt-chrome distal and posterior augment which are cemented in place. The augment have a 1 mm polymethylmethacrylate (PMMA) spacer to reduce fretting. The cobalt-chrome tibial trays may have 5°, 10° or 15° wedges or 5° or 10° half wedges. Both femoral and tibial components accept canal filling fluted stems of between 95 and 140 mm in length.

The Genesis I system has modular titanium 4 and 8 mm thick posterior and distal femoral wedges which are cemented onto the 11.5 mm thick cobalt-chrome femoral component (including conversion module). Titanium modular tibial wedges are available in thicknesses of 5 and 10 mm and are cemented on to the titanium tibial component. Femoral stems are available in lengths of 100, 150 and 200 mm and tibial stems are available in lengths of 40 and 90 mm.

All operations were under the direction of one of the two senior authors (CHR or RBB). The site and size of the augment was recorded, as was the length of stem. All stems were cemented using a hybrid technique with cement being applied to the prepared condylar surfaces and to the metaphyseal segment of the stem only. Antibiotic-loaded cement was used in all operations (Simplex, Howmedica, East Rutherford, New Jersey).

The thickness and distribution of the 176 femoral augment which were used is shown in Table III. Distal femoral augment were most commonly used. For the tibia medially, 5° wedges were used in four knees, 10° wedges in six knees and 10 mm stepped hemi-wedges in seven knees. Laterally, a 5° wedge was used in one knee. A thickened tibial tray was used to make up defects both medially and laterally in two knees.

The lengths of stems used in association with an augment are shown in Figure 2. Of the 102 knees, 32 were treated with a varus-valgus constrained polyethylene insert, and 70 with a posterior stabilised insert. Patients were evaluated clinically using Knee Society Scores. Standing anteroposterior and lateral radiographs of the knee were taken six weeks after operation and annually thereafter. The presence of radiolucent lines and osteolysis around the augment was recorded. Data were analysed in two groups. First the clinical outcome was identified with survivorship being calculated using the Kaplan-Meier method. The indications for re-revision were recorded. Secondly, those knees with

![Fig. 1a Fig. 1b](image-url)

Drawings showing a) unicompartmental femoral damage (AORI 2A) and an intact tibia (AORI 1), and b) deficient femoral condyle (AORI 3), and bicondylar damage to tibial metaphysis (AORI 2B).
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Radiolucent lines were compared with those without in order to identify any association with the grade of bony defect, a predilection for distal or posterior femoral augments, the revision knee system used, the level of constraint used and the clinical outcome.

Results
At the time of follow-up 15 patients (16 knees) had died without having had further surgery to their knee. The mean age of these patients was 68 ± 12 years (60 to 82) and the mean follow-up was 4 ± 2 years (1 to 7). Four patients (4 knees) were lost to follow-up and three (3 knees) refused or could not attend for review. There remained 79 TKRs (76 patients) with complete clinical and radiographic follow-up at a mean of 7 ± 2 years (5 to 11). The mean age of these patients at the time of surgery was 68 ± 9 years (41 to 84).

Clinical analysis. The mean pre-operative knee score of the 79 TKRs had improved from 87 ± 34 (20 to 165) to 137 ± 36 (80 to 199) at final follow-up. The mean pre-operative range of movement was 90 ± 22° (30 to 125), which improved to 100 ± 20° (30 to 130).

Six knees were re-revised, three for aseptic loosening of the tibial tray 1.3, 1.6 and seven years after surgery, respectively. One knee was re-revised the year after surgery for coronal instability associated with a posterior stabilised insert. Deep infection requiring two-stage re-revision occurred in two knees, in one the infection was recurrent. In none of these knees were there radiolucent lines or loosening of the augment. Survival calculated by the Kaplan-Meier method (Fig. 3) was 92 ± 0.03% at 11 years (95% CI, 10.3 to 11.2).

Radiographic analysis. Radiolucent lines were seen around 11 of the 79 knees (15.6%) where a femoral augment was used. Radiolucent lines could only be seen on the lateral radiograph and whether they occurred medially or laterally could not be reliably established. Non-progressive radiolucent lines developed at a mean of 2.7 years (1 to 5) after surgery. None were progressive or associated with clinical failure.

Pearson chi-squared tests did not demonstrate a significant predilection for radiolucenties to occur around the augment in 2A or 2B defects (p = 0.59), distal or posterior femoral augments (p = 0.75), Genesis or Co-ordinate knee systems (p = 0.36), or with the use of either a posterior stabilised or varus-valgus constrained polyethylene insert (p = 0.36). Mann-Whitney U testing of data failed to demonstrate poorer knee scores with radiolucenties around an augment (p = 0.28).

Discussion
Wedged tibial polyethylene augments were originally used by Jeffery et al.13 Currently metal augments are available in

| Table III. The thickness and distribution of 151 femoral augment devices used in 79 knees and the association with radiolucent lines |
|-----------------|-----------------|-----------------|-----------------|
|                  | Distal          |                  | Posterior       |
|                  | Cases (%)       | Mean thickness ± SD in mm (range) | Cases (%)       | Mean thickness ± SD in mm (range) |
| Medial           | 36 (24)         | 5.4 ± 1.8 (4 to 8) | 31 (21)         | 5.2 ± 2 (4 to 8) |
| Lateral          | 46 (30)         | 5.2 ± 1.8 (4 to 8) | 38 (25)         | 4.8 ± 2 (4 to 8) |
| Radiolucent lines| 2 (2)           | 9               | 9 (13)          |

The lengths of the stems used with the augments in 98 patients with type-2 bony defects who underwent revision TKR.

The cumulative survival following revision TKR for type-2 bony defects, re-revision for any reason was 92 ± 0.03% at 11 years (95% CI; 10.3 to 11.2).
wedges and blocks for femoral and tibial defects, which are about 1 cm thick. A number of advantages make augmentation devices used in revision knee arthroplasty appropriate for the management of bony defects. These devices allow for versatile intra-operative customisation. Asymmetric defects which may be encountered in the tibia and femur, do not require further resection of bone in order to produce a symmetrical bed to seat the prosthesis, thus preserving bone stock. Minimising the amount of tibial resection optimises the strength of the cancellous bone, which is available to support the component, as the strength of the tibial cancellous bone is inversely proportional to its distance from the joint line. Additionally, the conical shape of the proximal tibia causes relatively undersized tibial components to be used if the defects are not reconstructed. This may cause a mismatch between the size of the femoral and tibial components in some revision knee arthroplasty systems. For the femur, minimal resection of bone and reconstruction of defects with augments aids restoration of the joint line.21 Moreover, unlike bone grafts, cemented augment do not require healing to the sclerotic bed. In vitro evidence exists for greater loading of the tibia and a more stable construct with cemented metal wedges rather than cement alone when reconstructing uncontained tibial defects.10-12

Despite the widespread availability and perceived advantages, there are concerns regarding the use of augments in current revision knee arthroplasty systems. Fretting of modular implants has been reported at the morse taper interfaces of femoral components and could conceivably occur between the augment and the femoral or tibial interface.23-25 Disassociation of modular components in revision knee arthroplasty has also been reported.26 The shear strength of a cemented modular tibial metal augment, retrieved after 6.5 years in vivo, was 77% of that of a newly cemented augment.27 Wedge-shaped augments have been shown, in vitro, to be less stable than stepped and rectangular augment.10

Non-progressive radiolucent lines have been observed between 27% and 46% of augmented tibial compo-

Table IV. The results of nine previous studies of cemented revision knee arthroplasty using stemmed components

<table>
<thead>
<tr>
<th>Author</th>
<th>Number of patients</th>
<th>Diagnosis (% aseptic)</th>
<th>Bone defect treatment</th>
<th>Constrained inserts (%)</th>
<th>Follow-up (years)</th>
<th>Component survival (%)</th>
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</thead>
<tbody>
<tr>
<td>Bertin et al7</td>
<td>45</td>
<td>100</td>
<td>Cemented</td>
<td>0</td>
<td>1.5</td>
<td>90</td>
</tr>
<tr>
<td>Goldberg et al2</td>
<td>59</td>
<td>100</td>
<td>Bone graft</td>
<td>Rotating hinge (14)</td>
<td>5</td>
<td>90</td>
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<tr>
<td>Elia and Lotke3</td>
<td>40</td>
<td>100</td>
<td>Cement and graft</td>
<td>30</td>
<td>3.4</td>
<td>90</td>
</tr>
<tr>
<td>Friedman et al4</td>
<td>127</td>
<td>100</td>
<td>Cement and graft</td>
<td>Not reported</td>
<td>5.2</td>
<td>94</td>
</tr>
<tr>
<td>Murray et al5</td>
<td>40</td>
<td>100</td>
<td>Not reported</td>
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<td>4.8</td>
<td>98</td>
</tr>
<tr>
<td>Hartford et al8</td>
<td>16</td>
<td>50</td>
<td>Not reported</td>
<td>CCK* (100)</td>
<td>5</td>
<td>81</td>
</tr>
<tr>
<td>Haas et al10</td>
<td>76</td>
<td>100</td>
<td>Augments</td>
<td>CCK (25)</td>
<td>3.5</td>
<td>93</td>
</tr>
<tr>
<td>Takahashi and Gustillo6</td>
<td>39</td>
<td>77</td>
<td>Augments</td>
<td>0</td>
<td>2</td>
<td>97</td>
</tr>
<tr>
<td>Bugbee et al9</td>
<td>50</td>
<td>87</td>
<td>(27 AORI type 2) Augments</td>
<td>Not reported</td>
<td>≥5</td>
<td>94</td>
</tr>
</tbody>
</table>

* constrained condylar knee

ments.13,16,27 Pagnano et al13 described 28 primary TKRs with a mean follow-up of 5.6 years. There were no revisions associated with the augment, but 13 knees (46%) had radiolucent lines. Brand et al16 similarly reported radiolucent lines in 27% of knees in which tibial augments were used on 17 primary and five revision TKRs with a mean follow-up of 37 months. In our series, radiolucent lines were found around 15% of tibial augments. The stability of the component is, undoubtedly, partly determined by the use of stems.12,28,29 The extensive use of stems and the method of their fixation in this series may, in part, explain the reduced incidence of radiolucent lines and satisfactory results.

The use of femoral augments has, to date, been poorly reported, as has the use of augments in revision TKR where the surface area of contact between cement and prosthesis is reduced and bone quality poor.30 Radiolucent lines were observed in 2% of distal femoral augments and 13% of posterior augment (Table III). It is probable that the complex shape of the stemmed femoral component with augment obscures the full extent of radiolucent lines observed as does variations in the angle of radiographic projection. Once radiolucent lines were observed around the femoral augment, they were consistently detected on subsequent radiographs. Their presence did not correlate with the severity of the bony defect, manufacture of prosthesis, the amount of constraint used at the articulation, the Knee Score at follow-up or the requirement for further revision surgery.

It is difficult to compare the results of revision TKR without a universally accepted classification system for bony defects, particularly as there are few mid-term follow-up reports of revision TKR. Elia and Lotke1 described 10% failures in 40 revision TKRs with defects of 1 cm depth at a mean follow-up of 41 months. Bony defects were filled with cement and/or bone graft, and stems were used in all knees. The results of cemented revision TKR using stemmed components are summarised in Table IV. Our results with Kaplan-Meier survival of 92 ± 0.03% at 11 years, suggest satisfactory mid-term survival and compare favourably with previous reports of fewer patients and shorter follow-up using stemmed cemented revision TKRs.1-9
We have found the AORI classification to be helpful and simple to use. It does not, however, distinguish between contained and uncontained defects, nor are central cavitory defects accounted for. Contained defects could, alternatively, be treated with non-structural bone graft or cement. Of the 28 tibial defects, only 20 were treated with augmented components. This reflects the common practice of making up for tibial defects by using a thicker polyethylene insert. Our analysis did not control for variables known to affect the results of revision TKR, such as the cause of prosthetic failure and ligament insufficiency. Our aim was to present the results of a single method of reconstruction for a specific type of bony defect. In the absence of comparative trials, we hope that these results will enable alternative methods of reconstruction to be evaluated.

In conclusion, we support the use of modular augmentation devices to treat type-2 defects in revision knee surgery. We have observed 92% survival at 11 years in the treatment of these defects with metal augments, with no clinically significant complications and conclude that theoretical concerns of fretting and loosening are unfounded based on five-to ten-year clinical data.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

References