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CLINICAL RESEARCH

Cementless Revision TKA with Bone Grafting of Osseous Defects Restores Bone Stock with a Low Revision Rate at 4 to 10 years

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Abstract

Background Addressing bone loss in revision TKA is challenging despite the array of options to reconstruct the deficient bone. Biologic reconstruction using morselized loosely-packed bone graft potentially allows for augmentation of residual bone stock while offering physiologic load transfer. However it is unclear whether the reconstructions are durable.

Questions/purposes We therefore sought to determine (1) survivorship and complications, (2) function, and (3) radiographic findings of cementless revision TKA in combination with loosely-packed morselized bone graft to reconstruct osseous defects at revision TKA.

Patients and Methods We retrospectively reviewed 56 patients who had undergone revision TKAs using cementless long-stemmed components in combination with morselized loose bone graft at our institution. There were 26 men and 30 women with a mean age of 68.3 years (range, 56–89 years). Patients were followed to assess symptoms and function and to detect radiographic loosening, component migration, and graft incorporation. The minimum followup was 4 years (mean, 7.3 years; range, 4–10 years).

Results Cumulative prosthesis survival, with revision as an end point, was 98% at 10 years. The mean Oxford Knee Scores improved from 21 (36%) preoperatively to 41 (68%) at final followup. Five patients (9%) had reoperations for complications.

Conclusions Our observations suggest this technique is reproducible and obviates the need for excessive bone resection, use of large metal augments, mass allografts, or custom prostheses. It allows for bone stock to be reconstructed reliably with durable midterm component fixation.

Level of Evidence Level IV, therapeutic study. See Guidelines for Authors for a complete description of levels of evidence.

Each author certifies that he or she has no commercial associations (eg, consultancies, stock ownership, equity interest, patent/licensing arrangements, etc) that might pose a conflict of interest in connection with the submitted article.
Each author certifies that his or her institution approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.
This work was performed at Lister Hospital, East and North Hertfordshire NHS Trust, UK.

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Introduction

Primary TKA is one of the most effective procedures in modern surgical history to improve patients' symptoms, quality of life, knee ROM, and function [1, 16, 19, 39]. With the steady increase in primary TKAs performed annually, revision procedures are expected to increase substantially in coming years, with a projected increase of 601% from 2005 to 2030 [17, 31]. Failure of the primary TKA occurs in 5% to 10% of patients by 10 to 15 years [4, 8, 18, 32, 36] and is accompanied by a series of

challenges that make revision TKA difficult and with higher failure rates than the primary procedure [39, 41]; the rates range from 10% to 25% of patients by 9 to 10 years [4, 8, 18, 32, 36]. Failure almost always is accompanied by substantial bone loss in addition to deficiency and laxity in the adjacent ligaments [39]. Deficient bone stock adjacent to failed knee prostheses can occur secondary to numerous factors, including the original disease process, osteolysis associated with accumulation of polyethylene wear debris, infection, mechanical compaction, implant migration, multiple revisions, and spaces left by removal of the revised components and cement [31, 41]. Reconstructing knees with these deficiencies is challenging. Restoring bony integrity, in particular, is vital to achieving durable implant fixation with stable bone-implant interfaces and well-distributed compressive forces.

Several established reconstructive techniques are available for correcting bone loss with varying reported survivorship and function. These include cementing of contained defects [21, 29], the use of augments [6, 25, 26], modular and custom hinged knee implants [27, 28, 34, 43], and bone grafting (morselized bone [5, 20, 37–40, 42], structural allografts [2, 12]). The use of morselized bone, although widely used in revision hip surgery [3], has not been commonly reported in revision TKA studies. Two different techniques are described in the literature (impacted [5, 20, 42] and loosely packed graft [37, 40]). We have favored the use of loosely packed morselized bone to reconstitute bone loss when performing revision TKAs. Although we believe the approach is advantageous because it theoretically would create more bone if further revisions are necessary in the future, it is unclear whether the reconstructions are durable.

We therefore set out to determine the midterm (1) survivorship and complications, (2) function, and (3) radiographic findings associated with the use of cementless stemmed revision knee components in combination with loosely packed morselized bone graft to reconstruct osseous defects in revision TKA.

Patients and Methods

We retrospectively reviewed all 64 patients with a symptomatic failed primary TKA associated with bone loss who had a revision TKA using cementless long-stemmed components with morselized loose bone graft between 1999 and 2006. The indications for this type of reconstruction were: (1) limiting knee symptoms (pain and stiffness), (2) patient dissatisfaction with knee function, and (3) radiographic changes (progressive loosening with bone deficiency). There were no absolute contraindications specifically related to this type of reconstruction. Two of the 64 patients were lost to followup and six died from unrelated reasons. This left 56 patients available for review. There were 26 men and 30 women with a mean age of 68.3 years (range, 56–89 years) at the time of surgery. The minimum followup was 4 years (median, 7.5, mean, 7.3 years; range, 4–10 years). No patients were recalled specifically for this study; all data were obtained from medical records and radiographs.

Preoperatively, all patients were investigated to ascertain the type of implant failure and to plan the appropriate surgical intervention. All patients had the following investigations: full blood count, inflammatory markers (C-reactive protein [CRP], erythrocyte sedimentation rate [ESR]), weightbearing plain radiographs (AP, lateral, skyline), microbiology analysis (synovial fluid and/or tissue specimens), CT, and technetium (Tc^{99}) scintigraphy. Radiographic assessment using plain radiographs only is known to underestimate bone loss and further assessment with CT is sometimes necessary [22, 24]. Causes of implant failure in the 56 reviewed patients included aseptic loosening (37), deep-seated infection (14), patellar maltracking (three), periprosthetic fracture (one), and poor flexion (one). There were 42 single-stage revisions and 14 two-stage revisions (for infection). We classified bone loss using the Anderson Orthopaedic Research Institute (AORI) classification system described by Engh [11]. There were varying degrees of bone loss from mild to severe (Table 1).

We used the Profix® Total Knee System (Smith & Nephew, Memphis, TN, USA) in all our patients. It features a cobalt-chrome primary femoral component, titanium femoral and tibial stems, asymmetric titanium tibial component, a semiconstrained, moderately conforming polyethylene tibial insert, and an inset-designed polyethylene patella with a central fluted post. The components used in our study were all porous-coated. We implanted long smooth fluted stems with a slotted end to prevent toggle, resist axial loading, and provide rotational stability. Polyethylene inserts with a choice of two levels of conformity were used, but none were posterior-stabilized.

We used Whiteside's technique [37] in all our patients. All surgery was performed by the senior author (DPP). The procedure was performed with the patient in the supine position with a foot bolster and side support for the surgically treated knee. One dose of intravenous prophylactic antibiotic was given at induction. After preparation of the

Table 1. Breakdown of the cases in terms of degree of bone loss

Location/number of knees	AORI 1	AORI 2A	AORI 2B	AORI 3
Femur/64	18	21	19	6
Tibia/64	16	19	21	8
Femur/56	15	18	18	5
Tibia/56	13	17	20	6

AORI = Anderson Orthopaedic Research Institute.

skin and exclusion draping, a midline incision with a standard medial parapatellar approach [15] was used to expose the joint. After exposure, removal of the previous components and cement was performed using small osteotomes. This was performed slowly, methodically, and without force, with minimal stripping of soft tissues. We then assessed bone loss by direct observation of osseous defects and according to the AORI classification described by Engh [11]. A tibial tubercle osteotomy was performed in nine patients to aid eversion of the patella or to facilitate removal of the implants and cement. The tibial shaft was reamed sequentially with increasing size to cortical bone (a length of 150–200 mm in most cases to achieve correct alignment) until a tight fit was achieved in the diaphysis. We used the reamer as the alignment guide and once it was firmly fixed in the medullary canal, the cutting guide was applied over the shaft of the reamer. The tibia was resected at an angle perpendicular to its long axis. Rather than resect more bone to achieve broad seating of the tibial component, the rims were prepared so that at least 25% of the circumference of the rim was flat to achieve partial seating of the tibial base plate. We carefully reamed the femur in a similar manner to the tibia to 150- to 200-mm depth. The reamer was allowed to follow the track of the femur and care was taken to avoid penetration of the anterior cortex. A cutting guide then was applied and a minimal distal cut (5° valgus angle) was made just sufficient to provide one distal surface on which to base the prosthesis. We minimally recut the posterior condyles to allow the femoral implant to engage posterior bone and to provide a posterior surface to aid in rotational stability. Trial implants were inserted, flexion/extension balanced, and restoration of the joint line achieved using distal femoral augmentation where required. Rotational positioning of the femoral component was guided by the epicondylar axis. We inserted the tibial trial component so that the stem fit snugly but not tightly in the diaphyseal medullary canal with the tibial plate abutting against the remaining tibial rim. The trial spacer was inserted with the knee at 90° flexion. The definitive prostheses then were inserted using 1-mm-larger-diameter stems to assist in stable press-fit fixation. We augmented tibial fixation with screws into intact proximal tibial bone in eight early cases. Stem length was selected to be adequate to engage in the isthmus of diaphyseal bone providing toggle control and press-fit fixation on the femoral and tibial sides. We then prepared the graft by mixing freeze-dried morselized allograft (average particle size of 5 mm) with bony reamings from the femur and tibia with approximately 50 mL to 60 mL of the patient's blood. All bone defects, regardless of location, were lightly finger-packed and were not impacted. The soft tissues then were repaired and the wound closed. We did not treat uncontained defects differently as we believed the broad attachment of the medial quadriceps retinaculum, the capsular ligaments to the tibial flair, and the soft tissues adjacent to the femoral epicondyles provide an effective soft tissue sleeve around the knee, which can be tensioned adequately with the spacer effect of the implants, enabling effective grafting of these defects [39].

In cases with a deep-seated infection, we thoroughly and extensively débrided the knee after removing the old components and cement. Multiple specimens (fluid, synovial lining, bone) were sent to the laboratory for microscopy, cultures, and sensitivity analysis. An articulating antibiotic-impregnated knee spacer then was inserted. After repeated washouts with normal saline pulsatile lavage, the soft tissues and skin were closed. The patient was started on a broad-spectrum antibiotic until the microbiology results were available. Progress was monitored closely clinically and biochemically (leukocyte count, ESR, CRP) to ascertain the appropriate time to proceed to the second stage.

Eleven of the 56 patients were provided with a functional knee brace for 6 weeks postoperatively: two to protect intraoperatively repaired collateral ligaments and nine after tibial tuberosity transfer. The remaining 45 patients were allowed free ROM and mobility. In patients who had undergone a tibial tubercle osteotomy, full weightbearing and resisted active extension were delayed until 6 weeks postoperatively. Prophylactic intravenous antibiotics were given at induction and for two postoperative doses. Thromboprophylaxis consisted of elastic stockings and low-molecular-weight heparin.

Patients were followed at 6 weeks, 6 months, 1 year, and then on a yearly basis. Each visit included obtaining a thorough history and performing a full physical knee examination, documenting any abnormal findings, and evaluating active and passive ROM. Functional assessment preoperatively and postoperatively was performed using the Oxford Knee Score (OKS) [23]. This system is based on a questionnaire containing 12 questions related to activities of daily living, each with five categories of response. Each item is scored from 5 to 1, from least to most difficulty or severity, and combined to produce one score with a range from 60 (least difficulties) to 12 (most difficulties).

Serial standing AP and lateral plain radiographs of the knee were obtained preoperatively and postoperatively, at 6 months, and on an annual basis afterward. Radiographs were assessed separately by two reviewers; an independent radiologist (AGP) and by the first author (SAH) to assess interobserver variability. The analysis included recording the presence of radiolucent defects at the implant-bone interface parallel to the implant margins [14, 33]. Progression of these lines was recorded when there was an increase in width of 1 mm or greater in any zone. Osteolytic defects were defined as expansive lesions with scalloped margins [13]. The grafted areas were evaluated carefully at

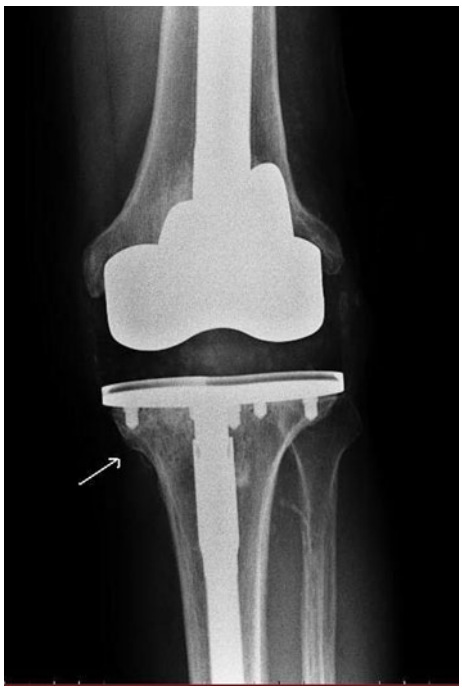

Fig. 1 Incorporation and consolidation with new trabeculations are seen across the graft site (arrow).

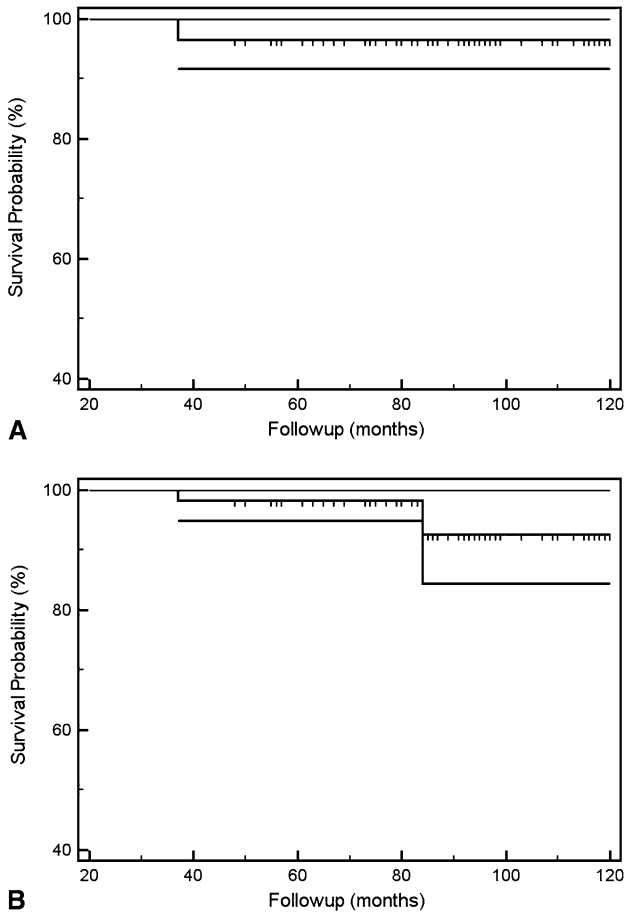

Fig. 2A–B (**A**) A Kaplan-Meier survival curve with failure of the prosthesis as an end point (need for further revision) shows implant survival of 98% at 10 years (95% CI, 94%–100%). (**B**) A worst-case survival curve with failure of the prosthesis as an end point (need for further revision), where both patients who had been lost to followup were presumed to require revision surgery at mean followup, shows implant survival of 92% at 10 years (95% CI, 84%–100%).

6 months postoperatively for evidence of change in density, blurring of interfaces in the graft and at the graft-host bone junction, and the occurrence of new trabeculations. Graft incorporation was described as present or not present. Incorporation is characterized by substitution of the old defective bone by living new bone as a result of creeping substitution [35] (Fig. 1). There was no interobserver variability in any of the radiographic observations.

We used a Kaplan-Meier curve to analyze prosthesis survival with failure as an end point. We defined failure as the need for any additional revision procedure to remove the prosthesis (Fig. 2A). A second curve was used to analyze the worst-case outcome presuming the two patients who had been lost to followup required revision of their prostheses at the mean followup time (Fig. 2B). We used SPSS® Version 17 (SPSS Inc, Chicago, IL, USA) for the analyses.

Results

Survival probability of the prosthesis was 98% at 10 years (95% confidence interval [CI], 94%–100%). The worst-case outcome, presuming the two patients who had been lost to followup required revision of their prostheses at mean followup, was 92% at 10 years (95% CI, 84%–100%) (Fig. 2). There were five additional surgeries in total, resulting in a 9% reoperation rate. These included a lateral collateral ligament reconstruction for instability, exchange of a polyethylene spacer, exploration of patella baja, Roux Goldthwaite procedure, and a two-stage revision to a knee fusion for persistent infection. We had two intraoperative complications. One patient had a complete avulsion of the patellar tendon from a previously transferred tibial tubercle and another had a partial avulsion. After fixation, the two patients were permitted partial weightbearing with no resisted knee extension exercise for 6 weeks after surgery. Both had intact extensor mechanisms and were able to achieve active full knee extension at latest followup. Two patients in this series had a persistent deep-seated infection (both in the two-stage revision group). In the first, the symptoms initially resolved with suppressive antibiotics but subsequently recurred and a two-stage fusion was required to eradicate infection at 37 months. The other patient currently is receiving long-term suppressive antibiotics. At the time of this review, the symptoms were manageable and the situation is closely monitored clinically, serologically, and radiographically.

The mean OKS improved ($p = 0.028$) from 21 (36%) preoperatively to 41 (68%) at latest followup. Of the 56 patients, 15 (27%) had no pain, 26 (47%) had mild-intermittent pain, 12 (21%) had moderate pain, and three (5%) had severe pain. The mean knee flexion was 98° (range, 45°–120°).

Three patients had progressive radiolucencies (5%). In two patients, these were adjacent to the tibial component and asymptomatic clinically. In the third patient, the radiolucencies were adjacent to the femoral and tibial components with poor graft incorporation. This patient had a persistent low-grade infection, which eventually required a two-stage fusion procedure at 37 months. There were also three non-progressive lucencies (5%) adjacent to the tibial component, all in the aseptic group. None of the patients had any correlating clinical symptoms and are being observed. No component migration occurred in this series. Incorporation and consolidation with trabeculations across the graft site were present in 54 patients (96%) and not present in two (4%) at 6 months postoperatively (Fig. 3).

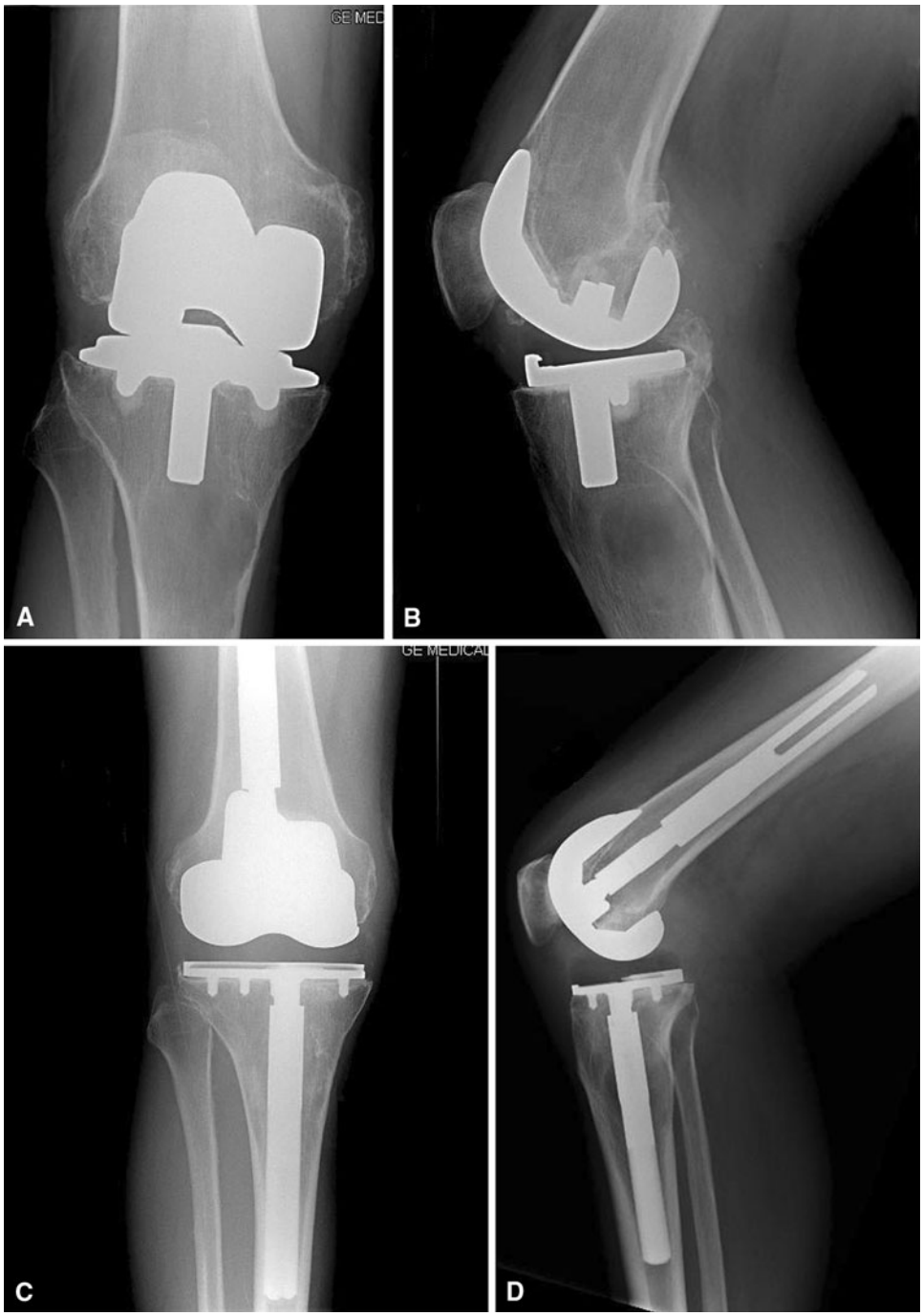

Fig. 3A–D (**A**) AP and (**B**) lateral radiographs show an aseptic loose primary TKA. Moderate bone loss with a contained defect is seen in the proximal tibia. (**C**) AP and (**D**) lateral radiographs taken 3 years postoperatively show stable components with good graft incorporation. The ROM is 0° to 100°, and the OKS is 46 (77%).

Discussion

With this study, we report encouraging midterm survivorship and functional results using cementless stemmed components in combination with morselized bone graft in revision TKA. The latter allows for reconstructing deficient bone stock adjacent to the failed prosthesis, which is advantageous because, theoretically, bone will be available if additional revisions are necessary in the future. Only bone grafting can reconstitute deficient bone stock, unlike other techniques used to address bone loss in revision TKA [6, 21, 25–29, 34, 43]. We therefore determined (1) survivorship and complications, (2) function, and (3) radiographic findings associated with the use of cementless stemmed revision knee components in combination with loosely packed morselized bone graft to reconstruct osseous defects in revision TKA.

There are limitations to this study. First, our study is retrospective and we have no control group with which to compare this technique. As such, our results should be interpreted with guarded optimism. However, we believe the low failure rate in the series at midterm and the occurrence of radiographic graft incorporation and bone stock restoration in 96% of cases is encouraging. Second, this is a one-surgeon and center study with relatively low patient numbers. The same limitation exists in most published revision TKA studies [2, 5, 6, 12, 16, 20, 21, 25–29, 34, 37–40, 42, 43], indicating the technically challenging nature of the procedure and the difficulty setting up a multicenter, multisurgeon study. Third, selection, measurement, and interviewer bias may have affected our functional assessment. However, we have addressed this by using a patient-based functional questionnaire (OKS) and by independently assessing the radiographs by two reviewers, a consultant radiologist (AGP) and a senior orthopaedic surgery trainee (SAH) to address interobserver variability.

Prosthesis survivorship in our study was 98% at 10 years with a 2% revision rate and a 9% reoperation rate. These results compare favorably with those of other published techniques (Table 2). Two studies have advocated using cement with or without screw fixation in cases with bone deficiency in TKA [21, 29]. The reported survivorship rates were 100% at 6 years [21] and 97% at 7 years [29]. Both studies, however, included patients undergoing primary TKA as opposed to revision TKA. Cement generally performs poorly in the long term, as it provides inferior load transfer with poor fatigue properties [10, 30], leading to failure. Published survivorship rates of augments underneath the tibial tray or to reconstruct femoral condylar defects range from 92% to 100% at short to midterm followup [6, 25, 26]. Using augments is a bone-sacrificing option rather than a preserving one, as resection of more bone may be required to accommodate them. Hinged knee implants also have been used in revision TKAs with bone deficiency [27, 28, 34, 43]. The reported survivorship rates range from 68% to 96% at followups ranging from 3 to 5 years. These devices are bone-sacrificing, expensive, and take time to manufacture [27, 34]. Bone grafting achieves comparable survivorship to the above techniques but with

Table 2. Results of primary and revision TKAs associated with bone loss using various reconstructive techniques

Study	Technique	Primary/revision TKA	Number of knees	Followup	Survivorship	Function
Lotke et al. [21] 1991	Cementation	Primary	59	7 years	97%	78%
Ritter et al. [29] 1993	Cement with screws	Primary	57	6 years	100%	91%
Brand et al. [6] 1989	Augments	Primary & revision	22	3 years	100%	ROM = 107°
Pagnano et al. [25] 1995	Augments	Primary	28	6 years	96%	82%
Patel et al. [26] 2004	Augments	Revision	79	7 years	92%	ROM = 90°
Springer et al. [34] 2004	Modular rotating hinge	Primary & revision	26	5 years	96%	75% ROM = 94°
Utting & Newman [43] 2004	Custom rotating hinge	Revision	30	3 years	87%	57%
Pradhan et al. [28] 2004	Modular rotating hinge	Revision	51	4 years	96%	72%
Pour et al. [27] 2007	Modular rotating hinge	Revision	44	4 years	68%	43%
Backstein et al. [2] 2006	Structural allografts	Revision	61	5 years	79%	-
Engh et al. [12] 2007	Structural allografts	Revision	46	8 years	91%	84% ROM = 103°
Ullmark & Hovelius [42] 1996	Impaction grafting	Revision	3	2.5 years	100%	ROM = 103°
Bradley [5] 2000	Impaction grafting	Revision	19	3 years	95%	73%
Lotke et al. [20] 2006	Impaction grafting	Revision	48	4 years	98%	80% ROM = 111°
Whiteside [40] 2006	Loose graft	Revision	110	8 years	98%	-
Current study	Loose graft	Revision	56	7 years	98%	68% ROM = 98°

the advantage of reconstituting bone stock. Structural allografts' survivorship rates range from 79% to 92% at midterm followup [2, 12]. No study has ever documented endosteal revascularization in massive allografts. In addition, allografts have some disadvantages, including the risk of nonunion and disease transmission [7, 9, 10]. Some authors find morselized bone a more versatile option as the graft can be easily contoured intraoperatively to fit the defect [41]. Two different techniques of applying these grafts have been described [5, 20, 37–40, 42], with impaction and without. Impaction grafting, which is widely used in revision hip surgery on the femoral and acetabular sides with good functional and radiographic results [3], also has been described in revision knee surgery with the use of cemented stemmed implants [5, 20, 42], with reported survivorship rates between 95% and 100% at short-term followup. Impaction grafting, however, requires a relatively large amount of bone graft, is expensive, time consuming, and technically challenging. The technique we used was first described by Whiteside [37], which involved using a mixture of loosely-packed cancellous allogenic and autogenic morselized bone with cementless press-fit titanium long-stemmed knee components.

Our patients achieved a mean OKS of 41 (68%) and a mean knee ROM of 98° postoperatively. This is comparable with results reported in other studies (Table 2).

Graft incorporation with clear trabeculations across the graft site occurred in 96% of cases, which is very encouraging. The prevalence of radiolucencies in our series was 10% in total. A revision procedure was necessary in only one patient. Reported rates of radiolucencies adjacent to the TKA prosthesis in studies describing techniques not involving bone grafting were: cementation alone, 77% [21]; cement with screws, 27% [29]; augments, 27%, 46%,and 16% respectively [6, 25, 26]; and hinged knee prostheses, 50% and 15% respectively [27, 34].

There are numerous reconstructive options to address bone loss in TKA (Table 2) including cementation with or without screws, use of augments (modular or customized), hinged knee endoprostheses (modular or customized), and bone grafting (morselized or bulk structural allografts). When choosing the most appropriate method, factors including the potential for additional revision, life expectancy, functional demand, and patient comorbidities must be considered. Our observations suggest a low failure rate, improvement in function, and durable fixation from 4 to 10 years, suggesting this technique is a reasonable and versatile option when reconstructing moderate to severe bone loss in revision TKA and obviates the need for excessive bone resection and the use of large metal augments, mass allografts, or custom prostheses.

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