Modified Hybrid Stem Fixation in Revision TKA is Durable at 2 to 10 Years

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Abstract

Background Hybrid revision knee component fixation, in which cement is placed in the metaphysis combined with a cementless diaphyseal engaging stem, provides ease of insertion, possibly improved component alignment, and easier removal if required, compared with fully cemented prostheses. The literature suggests the technique has a 2 to 5 year survivorship ranging from 81% to 94%.

Questions/purposes To confirm the literature we asked whether (1) a modified hybrid fixation technique is durable and reliable at an average 5-year followup, (2) this method of fixation provides clinical improvements as assessed by knee scores, (3) there are radiographic findings unique to this fixation technique, (4) the degree of knee constraint influences clinical performance or radiographic findings, and (5) end-of-stem pain is associated with this fixation method?

Patients and Methods We retrospectively reviewed all 83 patients who had 88 both-component revision TKAs using our modified hybrid fixation technique. We assessed

the Knee Society scores and evaluated radiographs for radiolucent and radiosclerotic lines. The minimum followup was 24 months (average, 65 months; range, 24–126 months).

Results Kaplan-Meier survivorship free of aseptic loosening was 100% at 5 years and 90% at 10 years. Postoperatively, the mean Knee Society pain and function scores both improved. Partial radiolucent lines were rare; two components were loose. We commonly observed radiosclerotic lines adjacent to stem extensions but these did not affect clinical scores or implant stability at last followup. Neither knee scores nor radiographic findings differed based on knee constraint. End-of-stem pain occurred rarely and was transient.

Conclusions Modified hybrid fixation of revision knee arthroplasty using a diaphyseal engaging stem and cementation only in the metaphysis is durable at a mean 5 years followup.

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

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Introduction

As the number of primary TKAs increases and patients live longer, the total number of revision TKAs subsequently performed continues to increase annually [18, 23]. In general, prosthetic survivorship, outcome scores, and ROM for revisions are inferior to primary arthroplasties with 10-year survival rates of 79% to 83% as compared with 93% to 95.5% [6, 16, 19, 21, 34]. Potential difficulties in revision surgery include a compromised soft tissue envelope, ligamentous instability, and inadequate bone available for prosthetic fixation [2, 25]. Although an expanding

availability of component sizes and augments has helped address some of these problems, the optimal method of prosthetic fixation in revision TKA remains controversial.

During revision TKA, stems enhance component stability by decreasing stress at the implant surfaces through load-sharing to the diaphyseal cortex which can protect remaining host bone and minimize component migration [9, 10, 32]. Roentgen stereophotogrammetric analysis supports that long cementless stems improve stability measured by least implant micromotion and subsidence [1, 35]. A canal-filling stem improves tibial fixation, especially in the presence of poor proximal bone, whereas proximal tibial coverage adds little additional stability. Increasing stem diameter for an interference fit further reduces component micromotion and improves superior/inferior stability [11].

However, controversy exists whether stems are best implanted with cemented or cementless fixation. Fully cemented stems, either long diaphyseal or short metaphyseal, have modest clinical improvements with final knee and function scores of 51 to 83 and 57 to 64, respectively, and near 92% survivorship at 4 to 10 years [24, 27, 37]. Potential advantages of cemented stems include local antibiotic delivery, immediate rigid fixation, and the ability for minor adjustments in prosthesis position if anatomic mismatches are present. Concerns, however, include lack of surgeon familiarity with cementing techniques, cement excessively extruding throughout the diaphyseal canal, and, most importantly, difficulty with implant and cement removal if necessary. The advantages of hybrid fixation, components inserted with metaphyseal cementation and cementless diaphyseal stems, include ease of insertion, improved coronal and sagittal plane alignment, and the potential for easier removal if required (Fig. 1) [19, 20]. Despite the apparently increasing use of this technique, few studies report the durability of this fixation method in revision TKA [22, 30, 33, 39]. These studies report near 5-year followup survivorship of 81% to 94% with aseptic loosening or infection being the predominant causes of failure. To enhance stability with a modified hybrid fixation technique, we believe three elements are necessary: a true press-fit with diaphyseal engagement, metaphyseal cement pressurization to provide proximal stability, and availability of offset stems to enhance component placement while maintaining maximal stem fixation.

The purposes of this study were to determine the following: (1) Is a modified hybrid fixation technique durable and reliable at an average 5-year followup? (2) Does this method of fixation provide clinical improvements as assessed by knee scores? (3) Are there radiographic findings unique to this fixation technique? (4) Does the degree of knee constraint influence clinical performance or radiographic findings? (5) Is end-of-stem pain associated with this fixation method?

Fig. 1A–B (A) AP and (B) lateral radiographs show the hybrid stem fixation method of metaphyseal cementation with press-fit stem extensions.

Patients and Methods

Using our joint registry we identified all 88 patients (93 revisions) from 1998 to 2003 who underwent revision TKA of the tibial and femoral components simultaneously. During this period, we performed a total of 444 TKA revisions in 381 patients. A hybrid cementing technique with a diaphyseal engaging press-fit stem was used in all cases. The indication for revision was aseptic loosening in 46 knees (52%), infection in 15 (17%), instability in eight (9%), osteolysis in seven (8%), rotational malalignment in six (7%), and stiffness in six (7%). Contraindications to using this technique include presence of adjacent orthopaedic implants precluding use of a stem, osteoporotic bone requiring a very large stem, or use of a rotating hinge prosthesis with an extended keel that does not require additional cementless stem fixation. None of these scenarios were encountered during this study period. There were 31 men and 52 women with a mean age of 68.8 years (range, 40–90 years) at the time of revision. Five patients died before the minimum 2-year followup leaving 88 revision TKAs in 83 patients who were followed for a mean of 65 months (range, 24–126 months). Six patients died during the study period at an average of 74 months from the index procedure (range, 35–96 months) and were included in the clinical and survivorship analyses. At latest followup of the patients who died, there were no clinical or radiographic indications for revision surgery. No patients were lost to followup.

Based on the Anderson Orthopaedic Research Institute bone defect classification [13], intraoperative evaluation of tibial defects revealed 52 Type 1 (59%), 21 Type 2a (24%), eight Type 2b (9%), and seven Type 3 (8%) defects. There were eight Type 1 (9%) femoral defects, 32 Type 2a (36%), 40 Type 2b (46%), and eight Type 3 (9%).

Templating of stem diameter and length and surgical procedures were performed by one of four surgeons (AGR, CDV, WGP, RAB) who specialize in adult reconstructive knee surgery. Tibial canal preparation begins with hand reaming 1 to 2 cm past the tip of the planned stem in a line-to-line fashion. A trial tibial stem then was used as an intramedullary cutting guide. Tibial component size was chosen with trial stems to determine whether a straight or offset stem better optimized coverage of the tibial plateau while allowing for appropriate component external rotation. Stem size ultimately was chosen based on intraoperative assessment so the trial component required 1 to 2 cm of impaction to ensure a tight diaphyseal press-fit. Similar steps were taken for femoral component and stem sizing and alignment, with the use of augments as needed, to ensure joint line restoration, appropriate external rotation, and prosthetic stability. In no cases did additional orthopaedic implants affect revision prosthesis stem length. Longer stems were used only if the shorter length was deemed insufficient to achieve diaphyseal press-fit. The least constrained articulation was used to provide appropriate knee stability. Premixed antibiotic cement was used (Palacos with gentamycin; Zimmer, Warsaw, IN, USA). Cement was finger-pressurized on the exposed bone surfaces and in the metaphyseal region which also can fill bone defects present during revision surgery. This cementation technique uses the metaphyseal region to provide additional support to the prepared flat surfaces and the diaphysis. Cement was placed around the metaphyseal portion of the tibial and femoral prosthesis just past the junction of the stem and the revision component (Fig. 2).

All cases used a system in which either straight or 4.5-mm offset titanium fluted solid stems were available (LCKK revision; Zimmer). Offset stem extensions were used more commonly on the tibial (64 of 88 stems [73%]) compared with the femoral side (26 of 88 stems [30%]) (Table 1).

Fig. 2 The assembled prosthesis is coated with cement around the metaphyseal portion of the component and includes the junction of the stem and femoral component.

Augments were used in 22 (25%) of the tibial reconstructions and 80 (91%) of the femoral reconstructions. Allograft was used in 23 (26%) cases; fresh-frozen cancellous allograft was used to fill contained defects in 19 cases and two femoral heads and two tibial structural grafts were used. The patella was revised concomitantly in 16 (18%) cases. A posterior-stabilized insert was used in 33 cases (38%) and a constrained condylar insert was used in 55 (62%).

These patients who had revision TKAs underwent similar postoperative protocols as patients undergoing primary TKAs. Ambulation was begun on the first postoperative day with weightbearing as tolerated with a walker, and transitioned to a cane as tolerated. Physical therapy provided ROM exercises daily. Continuous passive motion machines were not used. Patients began outpatient physical therapy after hospital discharge.

Patients were evaluated at 3-, 6-, and 12-week visits and then annually thereafter. Knee examinations were performed on each visit and radiographs were obtained at all but the 6-week visit. Clinical function was assessed by the operating surgeon [AGR, CDV, WGP, RAB] before revision and at latest followup using the Knee Society scoring system. Radiographs were reviewed as defined by the Knee Society and modified by Whaley et al. [37]. Radiographs were analyzed by two independent reviewers (AS, SS) for implant position and the presence of radiolucent or radiosclerotic lines. Radiographic evaluations varied in fewer than 8% of cases between blinded repeat measurements by one reviewer and between the two reviewers.

We determined differences in knee scores between preoperative and postoperative evaluations using the Student's

Table 1. Comparison of femoral and tibial stem extensions*

Stem Extension	Mean	SD	Most commonly used
Femoral stem width (mm)	16.7	2.2	17 mm
Tibial stem width (mm)	14.3	2.3	14 mm
	Short (100 mm)	Long (155 mm)	
Femoral stem length	81 (92%)	7 (8%)	
Tibial stem length	68 (77%)	20 (23%)	
	Straight	Offset	
Femoral stem type	62 (70%)	26 (30%)	
Tibial stem type	24 (27%)	64 (73%)	

* Shorter stems generally are able to be used in revisions. Offset stem extensions more frequently are used for the tibial reconstruction.

t-test. We detected no differences in knee scores based on level of knee constraint or presence of radioscletotic or radiolucent lines by Student's t-test. Neither radioscletotic nor radiolucent lines were different based on level of knee constraint with Fisher's exact test. Parametric tests were used and the data met the assumptions. Survivorship was analyzed using Kaplan-Meier curves [15] with 95% confidence intervals for reoperation for any reason and for aseptic loosening as end points. Statistical analyses were performed with GraphPad software (La Jolla, CA, USA).

Results

Kaplan-Meier survivorship free of reoperation for any reason was 92% at 5 years and 84% at 10 years (Fig. 3). Kaplan-Meier survivorship for aseptic loosening was 100% at 5 years and 90% at 10 years (Fig. 4). One tibial

Fig. 3 Revision knee surgery can be associated with increased rates of complications. In our series, the Kaplan-Meier survivorship free of reoperation for any reason was 92% at 5 years and 84% at 10 years.

Fig. 4 The modified hybrid fixation technique was durable with only two cases of component loosening at the conclusion of the study. The Kaplan-Meier survivorship free of aseptic loosening was 100% at 5 years and 90% at 10 years.

loosening occurred 89 months from revision (Fig. 5). One femoral loosening involved a femoral head allograft in the reconstruction and subsidence occurred 88 months after surgery. Neither component had an associated radioscletotic line before the diagnosis of loosening.

Revision knee arthroplasty with this modified hybrid fixation technique improved knee scores. At a mean of 65 months postoperatively (range, 24–126 months), the mean preoperative Knee Society knee score improved from 46 (range, 14–72) to 85 (range, 35–97) and function score from 48 (range, 20–80) to 68 (range, 20–95) points ($p < 0.001$ for both).

The presence of radiolucent lines was infrequent, found adjacent to 17 (19%) of the tibial and two (2%) of the femoral components. In all but two, one femoral and one tibial component in separate patients, the partial lucencies were 1 mm in width and nonprogressive. Two components were radiographically loose and subsequently revised as detailed previously. Patients with radiolucencies did not have inferior knee scores compared with those who did not ($p = 0.3$).

Radioscletotic lines were commonly visible around the stem extension, predominantly at the tip, in 66 (75%) of tibial and 57 (65%) of the femoral stems (Fig. 6). These lines did not progress with time. Knee Society function ($p = 0.50$) and knee scores ($p = 0.19$) were similar regardless of the presence or absence of radioscletotic lines.

Neither clinical knee scores nor radiographic findings differed comparing revisions with posterior-stabilized versus constrained condylar articulations. There was no

Fig. 5A–B (A) AP and (B) lateral radiographs show complete radiolucency around the subsided tibial component. A bone scan confirmed aseptic loosening of the component, which required revision.

Fig. 6A–B (A) AP and (B) lateral radiographs show the commonly present radiolucent lines adjacent to the press-fit stem extensions.

difference in function ($p = 0.18$) or knee scores ($p = 0.38$) depending on the level of knee constraint. Although increased stresses at the bone-cement interface are possible with constrained condylar prostheses compared with posterior-stabilized components, neither radiolucencies nor radiolucent lines were associated with level of knee constraint, $p = 0.19$ and $p = 0.39$, respectively.

Transient end-of-stem pain was rare, being present in only two tibias. With the majority of tibial stem extensions having adjacent sclerotic lines, and only two knees with transient tibial discomfort, no association could be made between end-of-stem pain and the presence of radiolucent lines. In both cases of end-of-stem pain, it resolved without intervention within 1 year.

There were no intraoperative or immediate perioperative complications resulting from prosthesis implantation with this technique. Nine knees (10%) underwent reoperations at an average of 40.3 months postoperatively (range, 5–89 months). Loosening of one femoral and one tibial component occurred, and both were revised as discussed previously. Two patients with deep infections, both requiring component removal 6 months after revision, had histories of multiple infections before the index revision procedure. Four acute hematogenous infections occurred on average 33.5 months after the index revision (range, 24–48 months), and both were treated successfully with debridement and insert exchange. One patient had a

periprosthetic fracture which occurred after a fall 35 months after revision surgery.

Discussion

Cemented stem fixation in revision TKAs is associated with survivorship greater than 90% with modest improvements in Knee Society pain and function scores at midterm followup [27, 37]. However, concerns with this technique include lack of familiarity with cementing techniques, cement excessively extruding throughout the diaphyseal canal, and difficulty and attendant bone loss with removal if necessary [12, 19]. Hybrid fixation has potential advantages including ease of insertion, improved component alignment, and ease of removal if needed. We describe a modified hybrid fixation technique, including pressurized metaphyseal cementation, availability of offset stems, and rigid diaphyseal stem press-fit. The purposes of this study are to evaluate the survivorship, clinical benefits, and radiographic features of this technique, assess if the degree of knee constraint affects these findings, and determine if end-of-stem pain is associated with this technique.

We recognize limitations to our study. First, the study is retrospective and a direct comparison group is unavailable. However, clinical improvements and survivorship with this technique are comparable to those reported in other studies. We continue to use this technique based on these results. Second, although multiple surgeons performed the revision surgeries, the technique was the same. Finally, longer followup is necessary to determine whether the radiographic findings are associated with clinical knee scores or implant durability. At this stage, no clear associations can be made based on our findings or by the available literature.

Studies with fewer patients at an average 18 to 42 months followup report improvements in knee pain and function scores ranging from 81 to 83 and 62 to 76, respectively, but moderate to occasional pain was present in 87% and fair to poor results in 16% [5, 8, 19, 29]. In these short-term studies, survivorship was 91% to 92% [5, 7, 19, 29] (Table 2). In contrast, others report high rerevision rates between 9% and 23% and 16% to 29% mechanical failure after only 2 to 6 years followup [8, 14, 33, 36]. In contrast to the aforementioned reports, we found reliable improvements in Knee Society scores and durability with 5-year survivorships from reoperation at 92% and aseptic loosening at 100%.

Comparison studies show longer press-fit stems that engage the diaphysis provide more consistent component alignment in the AP and lateral planes when compared with either short press-fit or cemented stems [5, 20, 24, 28]. In addition, offset uncemented stems improve the ability to

Table 2. Summary of literature review of hybrid component fixation in revision knee arthroplasty

Study (year)	Number of knees	Followup (months)	Total reoperations	Total revisions	Aseptic loosening revisions	Knee Scores (Knee then Function or total HSS)	Radiolucent lines		Radiosclerotic lines	Miscellaneous
							partial	complete		
Bertin et al. (1985) [5]	45	18	4 (9%)	0	0	NA	20 (59%) femur 23 (74%) tibia	6 (18%) femur	Present near 65 of 74 stems	
Haas et al. (1995) [19]	76	42	11 (14%)	6 (8%)	2 (3%)	49–76	8 (26%) tibia 22 (33%) femur	43 (64%) tibia 1 (1%) femur	45 (67%) femur 46 (69%) tibia	11 (16%) fair or poor results, 20% with moderate pain with activity, moderate pain at rest in 8 (11%)
Vince and Long (1995) [36]	44	24–72	5 (11%)	3 (7%)	2 (5%)	NA to 79 NA to 77	5 (7%) tibia NA	1 (2%)	NA	Metaphyseal cementation may be needed for constrained condylar implant stability
Peters et al. (2005) [29]	42	36	6 (14%)	4 (9%)	0 (0%)	49–87	2% femur, 4% tibia 0		NA	2 (4%) possible end-of-stem pain
Bottner et al. (2006) [8]	33	38	NA	3 (9%)	2 (6%)	42 to 83 48 to 76	NA 1 (3%)		NA	Moderate/occasional pain in 87% with walking
Peters et al. (2009) [30]	184	49	29 (16%)	15 (8%)	0	72 to 85 63 to 82	7 femur, 6 tibia 0		NA	
Gofton et al. (2002) [18]	89	70	8 (9%)	5 (6%)	3 (3%)	15 to 38 40 to 53	NA femur, tibial lines “not uncommon” 4 (4%) femur		55% femur 52% tibia	Suggest caution with hybrid fixation with higher level constraint
Shannon et al. (2003) [33]	63	69	15 (24%)	12 (19%)	6 (10%)	56 to 81 49 to 62	5 (6%) tibia 5 (10%) femur	36 (57%) tibia 0 (0%) femur	57 (90%) femur 61 (97%) tibia	Mechanical failure in 16%
Fehring et al. (2003) [14]	95	61	NA	NA	4 (4%)	NA	4 (6%) tibia 19% possibly loose	8 (8%) femur	NA	Only 67 (71%) of cementless stems recognized as stable
Wood et al. (2009) [39]	97	60	NA	6 (6%)	2 (2%)	38–86 32–55	2 (2%) tibia 19 (19%)	3 (3%)	90%	
Current study	88	65	9 (10%)	4 (5%)	2 (2%)	46 to 85 48 to 68	1 (1%) femur 16 (18%) tibia	1 (1%) femur 1 (1%) tibia	66 (75%) femur 57 (65%) tibia	

HSS = Hospital for Special Surgery; NA = not available or not reported.

optimally place the femoral or tibial prosthesis onto host bone while simultaneously maximizing diaphyseal stem fixation. This can enhance patellofemoral tracking through mediolateral component adjustments, aid the use of augments, and improve flexion-extension gap balance with AP placement of the femoral component. Offset stems were used overall in 51% of revision opportunities in our study patients; but in $\frac{3}{4}$ of tibial revisions, reflecting the mismatch of the tibial canal relative to the metaphyseal surface.

Lucencies occur adjacent to fully cemented tibial stems in 32% to 61% at 37 and 60 months followup [17, 27, 31]. Similarly, previous studies with hybrid fixation report partial lucencies occurring in 19% to 74% [5, 19, 33]. The rate of lucencies detected in our study is at the lower end of this range. Similar to our study, it is uncommon for these lucencies to progress, affect knee scores, or for radiographic loosening to occur. Peters et al. reported radiolucent lines were more prevalent adjacent to metadiaphyseal press-fit stems compared with cemented stems ($p < 0.02$) [30]. In addition, the predominant hybrid technique reported involves cement placed on bone surfaces, but metaphyseal cement is placed on the prosthesis only, rather than on the host bone [8, 14, 18, 19, 36, 39]. We believe our technique of pressurized metaphyseal cementation and rigid stem fixation may result in our lower frequency of radiolucencies.

Although offset stems and rigid press-fit may enhance durability of our technique, it produces radioscлерotic lines, similar to those reported in other studies of 52% to 97% [5, 18, 19, 33, 39]. These sclerotic lines are usually at the tip of the stem, nonprogressive, unrelated to outcome as assessed by Knee Society scores, do not appear to predict prosthesis failure, and the consequence remains uncertain [26, 38]. Some suggest that the radioscлерotic lines represent appropriate stress transferred through the stem highlighting its contribution to component stability, or that they are benign and related to canal preparation [5, 38]. Although these radiographic findings are not correlated with clinical scores or implant survival in our series, longer followup is required.

Vince and Long reported that the degree of knee constraint can affect revision implant survival in short-term followup [36]. They recommended against surface cementation only, because more failures occurred. With our rigid press-fit stem and pressurized metaphyseal cementation there were no differences in knee scores or radiographic findings between posterior-stabilized and constrained condylar devices. Therefore, in our series, modified hybrid fixation withstands the potential increased stresses of constrained condylar devices similar to a less constrained articulation.

Finally, end-of-stem pain has been reported with cementless stems in 11% to 20% [19]. However, in one of

these studies, three of 16 (19%) patients with cemented tibial stems also had end-of-stem pain [3]. Two patients in our study reported end-of-tibial stem pain which resolved in both within 1 year without intervention, which is similar to another report [4]. Also, whereas offset stems optimize component placement, they simultaneously allow maximal press-fit of the stem extensions into the isthmus, which otherwise may be compromised using straight stems only. We believe emphasis on this diaphyseal press-fit is important to minimize end-of-stem pain and to maximize component stability.

Revision TKA with modified hybrid fixation provides adequate fixation at intermediate-term followup. Revision for aseptic loosening with this technique is rare, occurring in only 2% of patients at completion of the study. Radioscлерotic lines adjacent to stem extensions are common, but do not affect outcome. The use of offset stems to optimize stem and component placement combined with stem engagement of the diaphysis and pressurized metaphyseal cementation may contribute to the durable fixation of this technique and simultaneously minimize end-of-stem pain.

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