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Survival outcomes of cemented compared to uncemented stems in primary total hip replacement

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Core tip: There has been a worldwide trend towards uncemented fixation in total hip replacement yet paradoxically cemented fixation has the highest survival rate when failure has been defined as a revision of the primary implant for aseptic loosening. However closer analysis of registry data shows that revision for aseptic loosening is low with uncemented total hip replacement, and in particular revision of uncemented stems is the lowest in young patients under 65 years, who would be expected to have higher physical demands with higher failure rates secondary to loosening.

Abstract

Total hip replacement (THR) is a successful and reliable operation for both relieving pain and improving function in patients who are disabled with end stage arthritis. The ageing population is predicted to significantly increase the requirement for THR in patients who have a higher functional demand than those of the past. Uncemented THR was introduced to improve the long term results and in particular the results in younger, higher functioning patients. There has been controversy about the value of uncemented compared to cemented THR although there has been a world-wide trend towards uncemented fixation. Uncemented acetabular fixation has gained wide acceptance, as seen in the increasing number of hybrid THR in joint registries, but there remains debate about the best mode of femoral fixation. In this article we review the history and current world-wide registry data, with an in-depth analysis of the New Zealand Joint Registry, to determine the results of uncemented femoral fixation in an attempt to provide an evidence-based answer as to the value of this form of fixation.

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INTRODUCTION

The best mode of implant fixation in primary total hip replacement (THR) has been a source of debate. Cemented implants achieve stability from cement-bone mechanical interlock, once the polymethylmethacrylate has cured, whereas cementless fixation relies on primary press fit stability with long term stability occurring secondary to endosteal microfractures at the time of preparation and subsequent bone ongrowth or ingrowth. The optimum fixation choice should be guided by patient based outcomes, in particular the implant survivorship as measured by revision for aseptic loosening, as this was

a major reason for the introduction of uncemented implants.

Advocates of cemented implants cite the excellent and reliable long-term reported survivorship^[1-3] whereas proponents of cementless fixation contend that this method is equally reliable^[4-7] and in fact superior in younger, high-demand patients^[8,9]. Furthermore, cementless implants provide a broader range of options especially for the acetabulum where liner exchange may be required for postoperative instability; the commonest cause for early re-operation in all primary THR^[10]. Modular cups also offer the option for changing the femoral head diameter which may improve the functional outcome especially in the younger or more active patient. A hybrid THR, where the stem is cemented and the cup uncemented, has been suggested to provide the benefits of both fixation methods^[11,12] although the reported results have been mixed^[13-15]. Worldwide there has been an observed trend towards uncemented fixation with confirmatory joint registry results in Australia, New Zealand, England, Wales and Sweden. Both Canada and the United States have continued to have a predominant use of uncemented THR^[14-18].

One of the traditional arguments against uncemented THR has been the increased cost with implants often being 3-4 times more expensive than the cemented variety. In the immediate future, the burden of an ageing population with the projected increase in demand for THR will put considerable strain on health funding agencies requiring balanced economic arguments for the use of THR implants. There is also likely to be an increase in the absolute number of revision procedures which are approximately 4 times more expensive than primary procedures, especially when both the femoral and acetabular components are revised. This has implications if one form of fixation is inferior to the other. Those that advocate uncemented implants suggest that following successful bonding of both the femoral and acetabular components to bone then future revision procedures may only involve exchange of articulating surfaces, which is likely to be a procedure whereby patients recover rapidly with a lower overall health cost^[19].

Uncemented acetabular implants are widely used in all age groups with registry results showing satisfactory early and mid-term results^[4,14-18]. However, uncemented femoral implants have been less widely accepted with several countries continuing to favour the cemented option as seen in the increasing number of hybrid THR performed in registries across the world^[15,18]. We have reviewed the recent evidence supporting femoral implant fixation, in particular joint registry outcomes, in an attempt to provide sound recommendations for future practise.

HISTORY OF FIXATION IN PRIMARY TOTAL HIP REPLACEMENT

The British Orthopaedic Association meeting in London, September 1964 was a turning point for the treat-

ment of patients with crippling osteoarthritis of the hip. McKee (Norwich) presented the results of the cemented metal-on-metal McKee-Farrar arthroplasty and Charnley (Wrightington) demonstrated the results of his cemented metal-on-polyethylene THR by having one of his patients walk normally across the stage. Widespread high rates of aseptic loosening of cemented THR during the 1960's and 1970's tempered enthusiasm and "Cement disease" was widely held as the cause of this loosening. Many surgeons began to favour the use of cementless fixation as recommended by Ring with his metal-on-metal replacement^[2]. However excellent results with cemented fixation were maintained with the Charnley prosthesis. The Exeter group, who believed that poor cementing technique and not cement *per se* was the issue, developed their collarless, taper-slip cemented prosthesis specifically designed to subside into the cement mantle while providing even load. The early metal-on-metal design soon fell from favour with high failure rates, possibly related to poor manufacturing tolerances of the implant, and the improving results of cemented metal-on-polyethylene replacements.

The high rates of early loosening and failures observed in younger, active patients coupled with concerns regarding "cement disease" continued to drive a renewed interest in uncemented fixation^[20-22]. Early failures of cemented implants in these younger patients were often associated with a varus positioning of the femoral stem whereas the acetabular component often failed after 12 years with polyethylene wear and loosening. The use of cementless components in this patient cohort initially established the wider use of these implants throughout the world in the hope that they would improve survivorship. Once it had been established that aseptic loosening was in fact due to the polyethylene debris and not 'cement disease' uncemented THR had become firmly established as a recognised and viable option for surgeons.

MODERN PRIMARY FEMORAL STEM

Over the last 20 years significant attention has been paid to improving the cementing technique which has emphasised both the preparation of the femoral canal and the pressurisation of the cement on insertion. These changes have improved the cement-bone interface with more stable inter-locking and as a result the intermediate survival rates of cemented stems have improved. Current joint registries record between 92% at 11 years and 86% at 22 years survival for these implants^[14,15,18]. These improved survival statistics have been interpreted as a cemented THR is likely to be a "life long" implant for patients aged sixty-two or older, whereas for a fifty-eight-year-old patient there is a 50:50 chance of undergoing a revision within their life time^[23].

There are currently two philosophies of cemented femoral fixation: composite beam and polished, tapered wedge. The former is predominant in North America whereas the latter is more widely used in Europe. A composite beam relies on rigid bonding to the cement and is

Table 1 Thirteen year New Zealand Joint Registry results for revision rates *vs* fixation method

Fixation	Component years	Events	Rate/100 cy	95%CI
Cemented	149098	870	0.58	0.55-0.62
Hybrid	168604	117	0.66	0.62-0.70
Reverse hybrid	3124	19	0.61	0.37-0.95
Uncemented	148214	1313	0.89	0.84-0.94

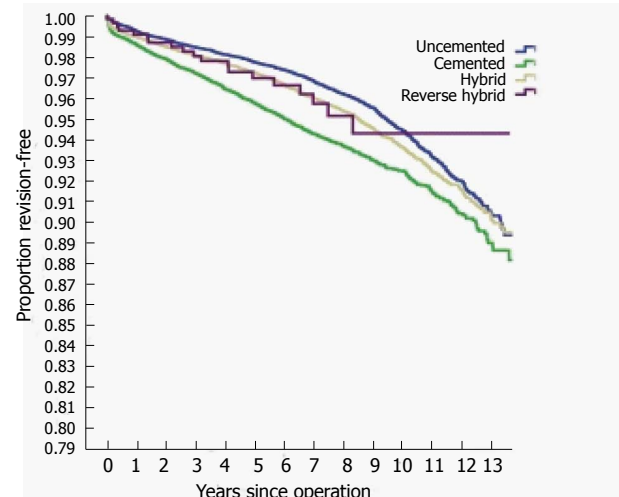
not intended to subside. This is in contrast to the loaded taper wedge which converts radial compression into hoop stresses within the cement mantle, and is expected to subside. The addition of cement around an implant provides an additional buffer that the surgeon can manipulate to control correcting leg length and version during insertion. Cement use has sporadically been reported as producing potentially fatal associated cardiovascular and embolic phenomena at implantation, especially in the elderly compromised patient^[24].

Cementless stems rely on bone on-growth or in-growth to provide stability. A roughened titanium stem has been shown to attract bone and provide early stability^[25] and most uncemented stems today have this type of surface. The addition of hydroxyapatite to this surface has been shown to also stimulate bony fixation^[26] without the initial early concern of producing ceramic particles in the joint that could cause third body wear.

There are two major uncemented stem designs: proximal (metaphyseal) loading or fully coated. Proximal loading has been advocated to avoid the stress shielding that was observed with early “distal fitting” implants^[27]. Often these implants are bulky in the proximal metaphyseal region, which is responsible for the early resistance to subsidence and rotation, and smooth distally to prevent bone apposition. They are inserted following minimal reaming and are rarely associated with femoral fracture. On the other hand, fully coated stems rely on a graduated loading of the proximal femur, allow bone apposition throughout their length and provide stability by their wide, flat nature. Initial stability is achieved by reaming the femur to accept a maximally sized implant that undergoes three-point fixation in the proximal femur. These implants require exact sizing and significant reaming and are associated with a higher incidence of femoral fracture^[28].

EUROPEAN JOINT REGISTRY OUTCOMES AND TRENDS IN FEMORAL FIXATION

The Swedish hip registry reports a gradual trend for the increased use of uncemented fixation although cemented THR's were used in 64% of all patients in 2011 regardless of age^[14]. Overall cementless stem fixation was more common in the younger, active patient with good bone quality whereas cemented fixation was favoured for patients over seventy years of age. Cemented THR had a 90% 16-year survivorship and was 30%-80% less likely to be revised compared to uncemented and hybrid THR's

**Figure 1** Thirteen New Zealand Joint Registry Kaplan-Meier survival curve of total hip replacement by fixation type.

during the first 8 years, suggesting that early revision was more likely to be related to acetabular problems. After 8 years the survivorship of the uncemented group tended towards that of the cemented group. Up to age 70 years the uncemented hips had fewer revisions attributed to loosening. The hybrid combinations did not convey a clear advantage over either group.

The Norwegian Hip Registry also reported an overall trend towards less cemented fixation but in Norway this was largely due to an increase in hybrid THR^[15]. Overall cemented THR's had a twenty-year survival rate of 85% compared to 50% for uncemented total hips. Hybrids had no clear advantage over either cemented or uncemented THR's in terms of implant survival during the same time period. Uncemented or hybrid fixation were preferred in patients under the age of 60 years whilst cemented fixation was used in the great majority > 60 years old.

In the National Joint Registry of England and Wales cemented THR represented only 33% of all primary THR's yet was used the majority of times for patients over eighty years of age^[19]. Total cementless fixation was used in 43% of patients and was the major type of fixation for patients less than seventy years old. Hybrid THR's accounted for 20% of primary THR's. The cumulative percentage of revision (with 95%CI) at 9 years was 2.71% (2.57-2.87) for cemented, 6.71% (6.40-7.05) for uncemented and 3.42% (3.10-3.76) for hybrid THR.

RESULTS FROM THE NEW ZEALAND JOINT REGISTRY

The data from the world-wide joint registries portray a similar pattern for the survival of cemented THR compared to uncemented THR, and these results are supported by those of the New Zealand Joint Registry (NZJR, Table 1 and Figure 1). On this basis it would be easy to dismiss the uncemented variety as inferior, but revision

Table 2 Thirteen year New Zealand Joint Registry reasons for revision for loosening within 90 d *n* (%)

Fixation/ <i>n</i>	Loose cup	Loose stem	Unstable	Deep infection	Pain	Femoral fracture
Cemented/77	6 (7.8)	3 (3.9)	58 (75.3)	9 (11.7)	9 (2.6)	3 (3.9)
Hybrid/189	31 (16.4)	7 (3.7)	113 (59.8)	26 (13.8)	5 (2.6)	9 (4.8)
Reverse hybrid/2	0	1 (50)	0	0	0	1 (50)
Uncemented/270	23 (8.5)	23 (8.5)	108 (40)	26 (9.6)	5 (1.9)	81 (30)

as an end point is a “blunt tool” and needs to be interpreted in conjunction with several other factors. We have reviewed the results of the New Zealand joint Registry in detail to elucidate this and to look at confounding variables that may contribute to these revision rates.

One of the primary reasons for the introduction of the uncemented stem was to improve the outcome in younger, more active patients, particularly males. The New Zealand joint registry has shown a revision rate of 0.89/100 component years (cy) for uncemented THRs in patients under 55 years compared to 1.73/100 cy for cemented THR and 0.90/100 cy compared to 0.98/100 cy for those between 55-65 years ($P < 0.001$)^[16]. Over 65 years this was reversed with the cemented THR surviving longer than the uncemented variety ($P < 0.001$). The overall revision rate was significantly higher ($P < 0.001$) in patients under 65 years (1.00-0.83/100 cy) compared to those over 65 years (0.65-0.45/100 cy) and an argument could be made that because of this the uncemented stem was more robust in a high demand patient. Hybrid fixation also showed poorer survival in the under 55 year group compared to uncemented THR (1.03/100 cy compared to 0.93/100 cy, $P < 0.002$) suggesting that it may be the uncemented stem in this age group which has helped improve the survival statistics.

Early revision (within 90 d) was far more common ($P < 0.001$) in the uncemented THR (0.899%) compared to cemented THR (0.353%) which continued across all age groups but only reached significance in those over 65 years ($P < 0.001$). When the reason for revision was analysed the major cause for early revision in uncemented implants was either due to femoral fracture (30%) or dislocation (40%) whereas 75% of early revisions in the cemented group were secondary to dislocation (Table 2). Femoral fracture with uncemented stems has been identified as an early cause for failure by others^[14]. Femoral fracture was shown to be age dependent, with older patients and presumably those with poorer bone density having a much higher incidence of this complication (Figure 2). This complication may be due to surgical inexperience and/or attempting to “over ream” the femur to insert the largest implant to avoid early subsidence or failure of bonding to the prosthesis. The early rate of femoral fracture did not continue beyond 90 d as the overall 13 year results showed there was no significant

Table 3 Thirteen year New Zealand Joint Registry reasons for revision for loosening by fixation method *n* (%)

Fixation/ <i>n</i>	Loose cup	Loose stem	Unstable	Deep infection	Pain	Femoral fracture
Cemented/870	415 (48)	148 (17)	200 (23)	105 (12)	86 (10)	74 (8.5)
Hybrid/1117	160 (14)	235 (21)	384 (34)	157 (14)	136 (12)	141 (11)
Reverse	4 (21)	1 (5)	5 (26)	4 (21)	2 (11)	3 (16)
Uncemented/1313	198 (15)	192 (15)	307 (24)	124 (9)	222 (17)	141 (11)
<i>P</i> value	< 0.001	< 0.001	< 0.001	0.003	< 0.001	0.208

difference in revision for femoral fracture between the fixation methods ($P = 0.208$) (Table 3). This contradicts the Swedish registry results which show that uncemented stems are revised twice as frequently as cemented stems during the first five years and that cemented stems were ten times less likely to require revision for periprosthetic fracture. The reason for this discrepancy is not immediately apparent.

The rate of femoral loosening within 90 d was significantly higher in uncemented stems ($P < 0.009$) but decreased over the 13-year period to become essentially the same as cemented stems (0.62% *vs* 0.66%). This early “loosening” of uncemented stems is likely to be associated with surgical technique and under sizing of the component, whereas the longer results are more likely to reflect the true aseptic loosening rate. Removing the early failures due to loosening makes the performance of the uncemented stem much more impressive and suggests that long term aseptic loosening may not affect it to the same extent as cemented THR. Figure 3 shows the increasing failure rate of cemented stem due to aseptic loosening compared to uncemented stems, suggesting that in the future this failure mode may remain static in uncemented stems but increase in the cemented variety. The fact that failure of hybrid fixation secondary to femoral loosening was 0.77% ($P < 0.001$) adds evidence to the suggestion that the cemented femoral stem may be more likely to fail by this mechanism. These results are supported by the Swedish registry which showed that from eight to sixteen years cemented stems had a higher rate of revision over cementless stems and 80% of these were for loosening.

In the past there has been controversy over the use of antibiotic loaded cement and whether this would decrease revision for prosthetic infection. Most have accepted that it was unlikely to do any harm, however the results from the NZJR are interesting when you consider that the great majority (> 90%) of cemented implants are performed with antibiotic cement. The combined revision rate for infection for both cemented and hybrid THR was 0.50% compared to 0.40% for uncemented THR which suggests that antibiotic cement may not have the protective effect against infection that has been assumed. This result is similar to the Swedish registry which demonstrated that cemented stems were 1.4 times more likely

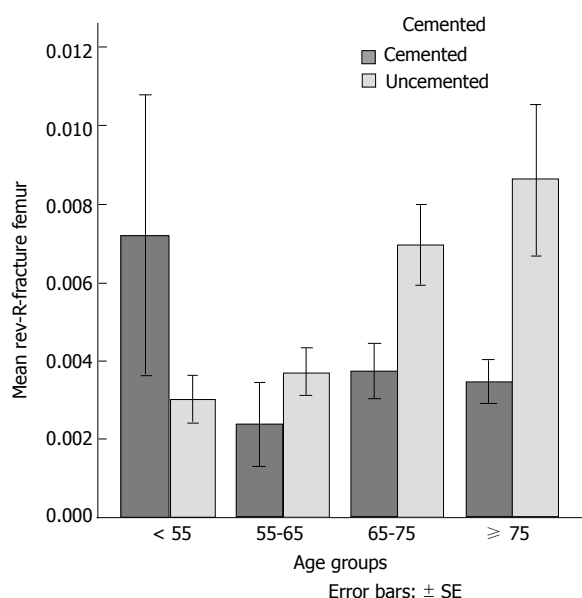


Figure 2 The New Zealand Joint Registry results showing the comparison of the incidence of femoral fracture and age with cemented and uncemented stems (65-75 yr, $P = 0.008$; ≥ 75 yr, $P = 0.001$).

to be revised for infection.

In the past unexplained pain has been a feature of the uncemented femoral stem but with a move away from distal fixation the incidence of revision for this complication was low at 90 d, however by 13 years pain became the second commonest cause for revision surgery behind dislocation in this group of implants. Pain as a cause for revision was not specified and so may not have been due to femoral pain. Regardless it is encouraging to find that pain was now a low cause for early revision of uncemented stems.

Another complicating variable which is unique to uncemented THR has been the ability to use different bearing surfaces in an attempt to improve the wear associated with a polyethylene articulation. Both metal on metal and ceramic on ceramic surfaces however have been associated with early failures due to reasons not associated with cemented THR. However most of these complications have arisen from the articulating surface itself, with ceramic fracture and excessive metal ion debris two of the primary reasons for early failure. These problems have not necessarily resulted in failure of the uncemented stem secondary to loosening and as a result have almost certainly skewed the overall revision rates in favour of cemented THR. The problem can be illustrated in the 14-year NZJR report where the revision rate for metal on metal articulations with femoral head size > 36 mm was 3.08/100 cy. The use of larger femoral head sizes is almost solely used in uncemented implants and those with a head size > 36 mm had a combined revision rate of 2.75/100 cy, irrespective of the articulating surface. This offers a potential explanation for the different revision rates between the two forms of femoral fixation.

IMPLANT COST

Although uncemented implants are more costly than ce-

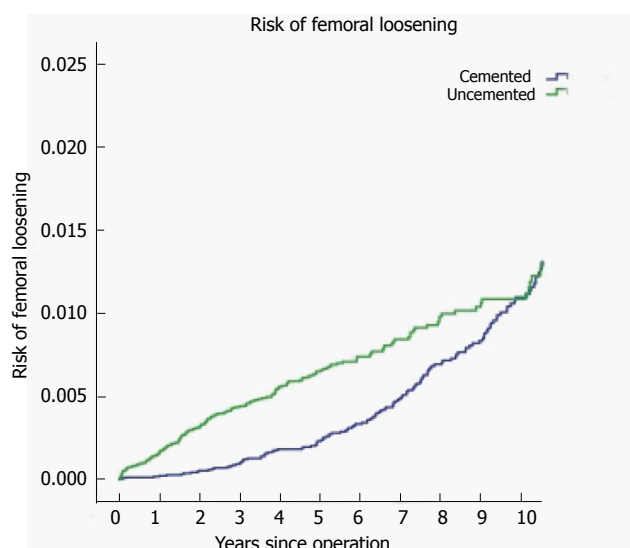


Figure 3 The New Zealand Joint Registry results showing the comparison between cemented and uncemented stems and the incidence of revision for aseptic loosening.

mented there have been studies suggesting that the overall cost differential between the two types of fixation is not dramatically different^[29,30]. With the increasing use of hybrid fixation the cost difference between a cemented and uncemented stem is even smaller and likely to be less relevant in the overall economic assessment. Determining the exact cost of a femoral stem can be difficult as the list price may be significantly different from the purchase price after discounting for bulk purchases and other company driven incentives. We cannot make a comment about pricing in other countries but are aware that companies in our country are required to price their implants in reasonable price bands to remain commercially viable and competitive.

CONCLUSION

Controversy continues to exist regarding the best form of fixation to use in THR. Often opinions are polarised by such factors as training, tradition, and personal preference with proponents of cemented fixation often citing the overall poorer revision rates for uncemented THR reported in the various national joint registries. This review has attempted to clarify the differences between cemented and uncemented THR, with the emphasis on femoral fixation, by analysing the reported joint registry data. There has been a world-wide trend towards uncemented THR over the last 10 years, and even countries who in the past have been the major proponents of cemented fixation have not been excluded from this trend.

Uncemented THR was introduced to address the poorer results observed with cemented THR in younger patients with higher functional requirements and to this end the registry results would confirm that inpatients < 65 years have a lower revision rate with uncemented fixation. In particular the uncemented stem has performed better in this age group with a lower rate of aseptic loos-

ening compared to the cemented variety. Femoral fracture remains a significant reason for early revision with uncemented stems which is more likely to be related to surgical technique and potentially could be improved by increased exposure to this technique in surgical training.

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