Cemented hip arthroplasty: why I do it

Jonathan R Howell

Abstract
Total hip replacement is an operation done to relieve pain and restore function and it is one of the most successful health interventions of the last century. Orthopaedic experience with cemented hip arthroplasty extends to over 50 years and in that time refinement of techniques and implants has led to components that offer the best long-term survivorship in almost all patients, as evidenced by research and registry data. However, long-term revision rates are just one of their advantages because cemented components also offer important benefits in their ability to restore patients’ anatomy, most importantly offset, leg length and component position as independent variables. The fine control that they offer to surgeons helps them to tailor each operation to the individual’s needs and thereby achieve the best result possible for every patient. In the long-term the presence of a well-fixed cement mantle offers the opportunity for cement-in-cement revision if further surgery is required. Components can be considered to be modular at the prosthesis/cement interface and the technique allows a surgeon to revise and return a patient to their primary state.

Keywords Anatomic restoration; lifetime costs; longevity; modularity in revision

Introduction
Total hip replacement (THR) has been described as the operation of the century and its success has meant that THRs are performed in ever-increasing numbers. Data from the National Joint Registry of England and Wales (NJR) has shown that in the decade between 2006 and 2016, there was an 80% increase in the number of THRs performed, from about 48,000 per year in 2006 to over 87,000 in 2016. The latest report from the NJR1 shows that the choice of fixation for primary THR remains divided, with 38.5% cases fully uncemented, 29.6% fully cemented and 28.1% standard hybrid cases, with a cemented femoral stem and an uncemented acetabular component. Therefore, we can see that about 58% of the THRs undertaken in 2016 were performed using a cemented stem. In this article we will consider both fully cemented THR and hybrid THR and will examine what advantages there may be in using cemented components.

The aims and risks of hip replacement surgery
Most patients undergoing total hip replacement do so to relieve persistent pain, which is not responding to other treatment modalities. Pain relief and greater joint mobility combine to improve patients’ function and quality of life. Since 2008 the patient reported outcome measures (PROMs) programme has collected data from THRs funded by the NHS in England. It includes an assessment of symptoms and functional limitations arising from the hip joint itself, the Oxford hip score (OHS), as well as quality of life (QoL) data using the EuroQol (EQ-5D-3L) proforma. Pennington et al.2 examined the PROMs data from 43,524 patients undergoing THR with three frequently used and successful examples of cemented, hybrid and uncemented hip replacements. All three methods of fixation produced significant improvements in PROMs, emphasizing the beneficial effect that well-proven designs of THR have on patients’ lives, regardless of fixation.

Patients undergoing THR surgery will frequently ask their surgeon how long the hip replacement can be expected to last and clearly longevity of the THR is important to both patient and surgeon. For much of the last three decades orthopaedic research has been focused on rates of aseptic loosening and lysis and this has undoubtedly led to improved materials, designs and techniques for insertion of hip replacements, be they cemented or uncemented. Data from the NJR show that the estimated 12-year revision rates for the majority of THRs is low, at less than 5%, and for the very best designs the rates are 2% or less.

However, loosening and lysis are not the only outcomes of importance, particularly for patients, for whom disappointment may arise from leg length difference, limp, persistent pain, instability and dislocation. Many of these problems have their root cause in a failure to adequately restore a patient’s individual anatomy and below we will consider how cement can assist a surgeon in achieving the best results for their patients.

Of course, regardless of how well or otherwise primary surgery is performed, revision surgery may be required in the future of a patient undergoing primary THR. Revision THR procedures are, in general, more complex and time-consuming than primary operations and they are associated with increased risks of intra- and post-operative complications. Choices made at the primary operation may help to facilitate future revision thereby mitigating the risks. We will therefore also examine how the use of cement may help in this respect.

PROMs, long-term results and economics
Patients undergoing THR do so for relief of pain, stiffness and restricted function in the hope of returning to a more active lifestyle. In the short term the results of the surgery can be assessed by PROMs and in the long-term both patient and surgeon wish to minimize the need for further intervention and therefore the survivorship of the operation will be of interest to both. The costs of hip replacement surgery to the provider may be calculated from the initial expenditure on the primary procedure, but the lifetime costs of the hip replacement, taking into account the costs of any revision procedures, are a more comprehensive method of assessment. Assessing the effect of THR fixation on PROMs, long-term results and cost-effectiveness is a complex process, confounded by a number of factors that include patient age, gender, baseline hip function, preoperative medical status and socioeconomic issues.

Pennington et al.3 looked at the functional outcomes and long-term results of the three most commonly used examples of

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cemented, hybrid and cementless hip replacements reported to the NJR. In 43,524 patients between 55 and 85 years of age undergoing primary THR for osteoarthritis they found that patients who received a cemented THR were older and more likely to be female, to live in a socioeconomically deprived area, to have at least two co-morbidities and to have an American Society of Anaesthesiologists (ASA) grade of more than 3 compared to patients receiving cementless prostheses. Furthermore, compared to those having cementless THRs, recipients of cemented hips reported more severe preoperative symptoms and poorer function, with lower Oxford hip scores, as well as a poorer preoperative quality of life as measured by the EQ-5D. The results of their study showed that the symptoms, function and quality of life of patients in all three fixation groups improved significantly. Minor differences were seen between the groups in their mean postoperative OHSS (cemented 37.7, cementless 39.2, hybrid 39.4) but baseline differences between them probably explain much of this variation. Using data from the NJR and national PROMs project, Jameson et al. found a similarly small difference in the PROMs for hips with different fixation methods, which the authors felt had reached statistical significance because of the large numbers involved, but not clinical significance.

Interestingly, both papers found a significant difference in the revision rate across the fixation groups, with the lowest rates of revision exhibited by the cemented THRs and the highest rates by cementless THRs, with hybrids occupying an intermediate position. Although it might be assumed that such differences in revision rates can be attributed to preoperative demographic differences this does not seem to be the case. Pennington et al. calculated hazard ratios for revision adjusted for age, sex, body mass index, ASA grade, Charlson score, surgeon grade and hospital type. Compared to those with cemented total hip replacements, recipients of cementless implants had an increased adjusted hazard ratio for revision of 1.66 (p < 0.001) and for patients with hybrid THRs it was 1.26 (p < 0.001). It is worth remembering that these results pertain, not to all implants on the NJR, but to the most commonly used three examples of each and therefore to prostheses that have been widely used and tested.

The results above were calculated over the short to medium term, so what about long-term fixation with cement? We have come a long way since Jones and Hungerford wrote about ‘cement disease’ in 1987. Their misguided conclusion that cement itself was responsible for osteolysis and loosening led to a parting of the ways of orthopaedic surgeons on each side of the Atlantic. In broad terms surgeons in the USA have pursued a cementless path, seeking to avoid the use of cement, which had been inappropriately blamed as the cause for osteolysis. Sadly, osteolysis was not abolished by the introduction of cementless fixation and indeed the combination of poor-quality polyethylene, metal-backed uncemented shells and defective locking mechanisms resulted in massive osteolysis for many thousands of patients. These issues have been addressed in large part through improvements in materials and implant design.

In contrast, in the UK considerable effort was expended in improving the results of cemented THR, through understanding the relationship between cement and stem design and by improvements in surgical technique that have produced excellent long-term results. The taper slip design of stem works with the long-term viscoelastic properties of cement, namely creep and stress relaxation, subsiding tiny distances and loading the cement in compression in which it is strongest. Research from our centre and others has shown that the combination of a polished, tapered cemented stem and a modern cementing technique produces long-term results that in all ages are at least as good, if not better, than those reported for cementless fixation. Similarly, improvements in acetabular cementing technique that include exposure of cancellous bone, drill holes for macro-fixation, bone cleaning, cement pressurisation and the use of a flanged cup have led to significant improvements in the results of cemented cups with up to 100% survivorship for aseptic loosening at 12.5 years.

The favourable long-term results of cemented hip replacement reported by individual centres are supported by results from the national joint registries. The latest annual report from the NJR presents the results now out to 13 years and it shows that the rate of revision across all patients is lowest in the all cemented group, regardless of the bearing used. The lowest rates of revision are seen when a ceramic on polyethylene (CoP) bearing is used with cemented components, for which the 13-year revision rate is 3.81%. This compares with 4.49% for uncemented THRs and 4.21% for hybrid hips. For THRs with metal on polyethylene bearings the results show a similar pattern with 13-year revision rates for cemented, uncemented and hybrid hips 4.25%, 5.90% and 4.94% respectively.

It might be assumed that these results reflect the effect of patient age on the outcome of THR and indeed the NJR does show an inverse relationship exists between patient age and THR survivorship. However, for the first time the latest NJR report includes an analysis of the effect of age and gender on outcome across the different fixation groups and again they favour cemented fixation, be that fully cemented or hybrid fixation. For women under 55 years of age the best results are with a cemented THR and a CoP bearing, for which the 10-year revision rate is 3.79%. The corresponding figures for uncemented and hybrid THRs are 4.27% and 3.66% respectively. For men under 55 the pattern of results is similar; cemented THRs combined with a CoP bearing showing lower revision rates than uncemented THRs at all time points, with hybrid hips also showing better survivorship than fully uncemented. For patients of both gender in the 55–64 and 65–74 age groups the patterns are again broadly similar with the best results exhibited by cemented and hybrid fixation, followed by uncemented THR.

These findings are not unique to the NJR. The Nordic Arthroplasty Registry Association (NARA) was established in 2007 by Sweden, Denmark and Norway with Finland joining later, in 2010. It was formed to facilitate research through the combined registries of those countries and the number of hips recorded rivals that of the NJR, but with longer follow-up. They have published on the failure rates of hips from the different fixation classes and the results are strikingly similar to those of the NJR. Including patients older than 55 years and breaking the results down into three age ranges, NARA demonstrates that for patients 65–74 years old and for those over 75 years the 10-year survival for cemented implants was higher than both uncemented and hybrid hip replacements. For patients 55–64, the survivorship of cemented and uncemented hips was similar.
Despite the evidence NARA has witnessed an increasing trend towards use of uncemented implants in Nordic countries. In seeking to explain this, the authors said 'In our opinion, intense marketing of more expensive uncemented implants by industry has strongly influenced the current trend.'

As for results in younger patients, who we know fare less well in long-term survivorship, NARA has published an analysis of 29,588 THRs done for osteoarthritis in patients under 55 years of age, which shows no difference between cemented and uncemented hips in the all-cause revision rate. The Australian registry has also made an in-depth analysis of the results in patients under 55 years and concluded that when non-cross-linked polyethylene is excluded from the analysis ‘there is no difference in the rate of revision with different types of fixation.’

Not only do the results from research and registries support the use of cemented components, so does economic data, which show that cemented THRs are also the least expensive. In an analysis of NJR data, Griffiths et al. looked at the cost savings that might be possible if all THRs performed in England and Wales were cemented. They found that the potential initial saving at the time of primary operation was £10 million and, taking into account the lower revision rates of cemented THRs, there was an additional potential saving of between £5 million and £8.5 million over the subsequent 5 years. Other authors have reported similar results. Using data from NHS supply chain and NHS Wales on the actual prices paid for implants including discounts, Jameson et al. calculated the average (mode) cost of the most commonly used examples of each fixation type of hip replacement and resurfacing. They found that the material costs were lowest for the cemented implants, which ranged from £1103 to £1524, and were highest for uncemented THRs, which ranged from £1928 to £4285. The costs calculated in this study included those of accessories, such as cement, restrictors and pressurisers for cemented hips and screws for cementless, but they did not include the theatre time costs, which might be lower for cementless hips if they are quicker to perform. However, theatre time and costs were included in an analysis performed by health economists at the Department of Health Services Research and Policy, London School of Tropical Medicine. They calculated the lifetime costs of the different fixation methods for hip replacements in patients aged 60, 70 and 80 years. They found that for all age groups the lifetime costs were lowest for cemented hip replacements and highest for cementless THRs and that revision rates were lowest for cemented implants in patients aged 70 and 80, with no difference in survivorship seen in patients aged 60. In their conclusion, they stated ‘Cementless prostheses do not improve health outcomes sufficiently to justify their higher costs.’

The same group went on to publish a brand analysis of lifetime costs of three commonly used examples of cemented, cementless and hybrid THRs in male and female patients aged 70 years. Again, they found that lifetime costs were lowest with cemented implants and higher for both cementless and hybrid THRs.

There are, therefore, compelling data from multiple sources that cemented hips are successful in relieving symptoms and improving quality of life, that they have better survivorship in most cases than uncemented hips and that they have the lowest lifetime costs to the healthcare providers. Let us now consider what other advantages they confer to both their recipients and users.

**Anatomic restoration**

Musculoskeletal function is closely related to structure and a surgeon undertaking a total hip replacement must make every effort to recreate a patient’s anatomy, in order to achieve the best performance possible from every joint replacement. For THR this means recreating three essential parameters: offset; leg length and component position. In this section we will look at how the use of cemented components can help a surgeon control each one of these parameters independently, thereby facilitating anatomic restoration.

**Restoring offset**

Offset is defined as the horizontal distance between the centre of rotation of the hip and the central axis of the femur, and is directly related to the lever arm of the abductors. Recreating the correct offset for each patient is important to ensure that the abductor muscle function is optimized and the joint reaction force is minimized, thereby reducing the risk of bearing wear and implant loosening.

In addition to its influence on the abductor muscle function and joint reaction force, changing offset has a number of other potential effects. These include joint instability and dislocation when the offset is reduced; and pain, disruption of joint balance and motion, and cosmetic problems where offset is excessive. The consequences, therefore, of failing to restore an individual’s offset are considerable, which is why it is so important that a surgeon works with a hip replacement system that allows control of offset as an independent variable.

Unfortunately, many hip replacements systems have progressive offsets, which increase as the stem size increases. This is particularly a problem for cementless stems, which must by their design fill the femoral canal to achieve fixation. If offset is dependent upon stem size then the offset that a patient receives from their hip replacement will be determined, not by their native offset, but by the dimensions of their femoral canal. Figure 1 shows two patients with different femoral anatomic characteristics that may pose a challenge for progressive offset designs of uncemented stem. Figure 1a shows an elderly female with a relatively capacious canal and a small native offset that measures 35.5 mm. In Figure 1b, Patient 2 is a middle-aged male with a narrow femoral canal and a large native offset that measures 56 mm. A progressive offset design of uncemented stem will tend to overstuff the offset for Patient 1 because a large stem size will be needed to fill her canal to achieve fixation. In contrast, Patient 2 will only accept a narrow stem, so the offset will be underdone if it is dependent upon stem size. It is scenarios such as these that led to the development of modular neck uncemented stems, which allowed alteration of offset angle and length, but which have now been largely abandoned because of their disastrous failure rates.

The use of cement can mitigate these risks. Figure 2 shows some of the stems from a cemented hip system in which the offset is independent of stem size. The use of such a system combined with cement allows the surgeon to use the correct offset for each patient and, as the templating images in Figure 1 show, the capacious canal of Patient 1 can be accommodated by
a slightly thicker cement mantle with a small offset stem, whereas for Patient 2 a narrow, higher offset stem combined with a thinner cement mantle will allow the surgeon to restore the patient’s anatomy.

**Leg length**

Leg length discrepancy following total hip replacement is poorly tolerated by patients and is one of the most common causes for patient dissatisfaction and legal action. Assuming that the acetabular component is placed at the correct centre of rotation, the leg length should be purely a matter of how deep the stem is inserted. Collarless cemented hip replacements offer an advantage over cementless designs in their ability to control leg length to within a few millimeters because a surgeon inserting such a stem into a polymerizing cement mantle has complete control over the depth of stem insertion and therefore the leg length. To make a leg longer the stem can be left more proud and to shorten the limb the stem may be sunk deeper. This is in stark contrast to the experience many surgeons have with cementless stems, which must be inserted until they make firm contact with host bone. If at that point the leg is too long the surgeon does not have the option of sinking the stem further to shorten it because of the risk of femoral fracture. It is, therefore, perhaps not surprising that medicolegal claims for leg length discrepancy are significantly more common with uncemented components than they are with cemented.

The technique of optimizing leg length used by the author is illustrated in Figure 3, which shows a man in his 50s who has previously had a left hybrid THR and now presents for a right THR. He has a high offset femur (offset of stem on left side is 50 mm) and a varus hip with a narrow femoral canal. This combination of morphology poses a risk for lengthening the leg when the right THR is performed. His preoperative leg lengths are equal so it is imperative that we do not lengthen the right in his next operation. In the preoperative plan (Figure 3a) the position of the 54 mm diameter socket matches that of the other side and the stem position has been planned to avoid a change in leg length. Having determined where the components should go, we then measure the vertical distance from the tip of the greater trochanter (GT) down to the shoulder of the prosthesis, which in this case is approximately 17 mm. Intraoperatively we mark the rasp handle with the distance above the stem shoulder that was measured on the preoperative template (Figure 3b). The rasp is then inserted until the mark on the rasp handle is level with the GT (Figure 3c), at which point the stem is at the correct depth and a trial reduction is performed. Further fine adjustment of rasp position and/or neck length can then be made to ensure the hip is balanced, stable and has a good range of motion (Figure 3d).

Halai et al. have published on this technique for planning leg length, comparing a test group of 50 patients in whom it was used with a group of 50 controls for whom it was not. Their paper (which includes an excellent description of the technique) showed a significantly lower postoperative leg length difference in the test group (mean difference 1.3 mm) compared to the control group (mean difference 6.3 mm, p < 0.001). Indeed, using the Exeter technique of leg length planning they have reported the lowest postoperative leg length difference in the world literature.

**Component position**

In order to achieve the best range of motion and the lowest risk of dislocation it is essential for a surgeon to place the components in the correct position and in this regard anteversion of the stem and cup as well as inclination of the acetabular component are of paramount importance. The presence of a flexible cement mantle during implant placement allows the surgeon to fine tune position of the components during insertion, rather than having to accept where the components seat themselves, as is frequently the case for uncemented hips.

It is a familiar experience when inserting an uncemented stem that the version of the femoral component is dependent upon the proximal morphology of the host femur. This inability to control femoral component version was another driver behind the development of modular femoral necks on uncemented implants, because they gave surgeons the option to add or remove femoral anteversion. No such modularity is needed for cemented hip...
Figure 2 A range of cemented stems of different length and size in which offset and stem size/length are independent of each other. For any given femoral canal diameter (stem size) the surgeon has a range of offset options to choose from.

Figure 3 Method for achieving the desired leg length in total hip replacement. (a) The preoperative plan shows the depth of stem insertion given by the trochanter to stem shoulder distance. (b) The trochanter to stem shoulder distance is marked on the rasp handle. (c) The rasp is inserted until the mark on the rasp handle is level with the tip of the greater trochanter. (d) The postoperative X-ray shows that equal leg length has been achieved.
replacements because the presence of the cement mantle allows the surgeon to vary the degree of anteversion to match what the patient needs for a stable hip.

The facility that cemented prostheses offer to surgeons in fine tuning their position and the advantage that they have in this regard over uncemented ones may explain why one study found significantly more legal complaints were made with uncemented components for cup malposition \( (p = 0.036) \), stem malposition \( (p = 0.004) \) and leg length \( (p = 0.035) \). For the future, robotic assistance with component positioning offers the potential for further refinement and accuracy. Cemented components, and in particular the stem, seem to lend themselves perfectly to robotic insertion, offering as they do the ability to tailor component position to match the patient’s requirements.

**Cement-in-cement revision: revise to a primary**

Whenever a surgeon undertakes a primary arthroplasty there should at least be some consideration given to the likelihood that further surgery will be required in the future and how choices made at the primary operation may affect the future situation. This becomes more important for younger patients and for those with more complex problems, both of which groups are statistically more like to require surgery in the future.

Over the last 15 years or so the concept of cement-in-cement revision has gained traction in hip arthroplasty and it is now an accepted revision technique. There are several publications in the English language supporting its use on the femoral side, including in multiply revised patients.

Depending on the indication for revision surgery, and on the presence of a well-fixed cement mantle, the technique involves removal of the cemented component, leaving the cement in place and the cement/bone interface undisturbed. The revision surgery is carried out and a new component cemented into the existing mantle, achieving fixation though a chemical bond that forms between the old cement and the new. On the femoral side the technique has been reported most widely with collarless polished stems, which are easy to remove and re-insert. It has several potential advantages including avoidance of the complications that may arise from removal of cement, easy femoral component removal to facilitate socket exposure and reduced operating times. Furthermore, the surgeon has the option of using a slightly smaller stem within the cement mantle if a change in leg length, offset or anteverision is needed. At the end of the procedure a new stem is cemented into the old mantle and because the cement/bone interface has been left intact the patient is essentially revised to the same state that they were at the primary hip replacement — ‘revise to a primary.’ We have now come to view cemented polished collarless stems as being modular at the stem/cement interface, which emphasizes their flexibility at future operations and represents yet another advantage to patient and surgeon of their use at the primary operation.

**Cement: are there downsides?**

Thus far I have discussed only the positives in using cemented fixation but of course a surgeon must consider the disadvantages of any choices that they make, as well as the advantages. We must therefore consider what the disadvantages may be of using cement for fixation in THR surgery.

**Theatre time**

It is often said, in support of the use of uncemented hip replacements, that they are quicker to perform and it seems to make inherent sense that this would be the case because there is no need to allow time for the cement to set. There is, in fact, limited evidence in the world literature to support this view but in a study of the Norwegian Arthroplasty Register, Smabrekke et al. compared the operating times for 28,890 cemented hip replacements and 2855 uncemented. On average they found that total operating times were 10 minutes less for uncemented components, but there were wide variations between high- and low-volume centres and between surgeons of different experience. This makes the point that fixation of the components is only one consideration in a multifactorial process that affects the overall efficiency of an operating theatre list. There certainly seems to be very little evidence in the literature that changing from cemented to uncemented hip replacements actually increases daily throughput of an operating theatre team.

**Patient safety**

Polymethylmethacrylate cement has been used in clinical practice for five decades and millions of patients have safely undergone cemented hip replacement without complication. However, there is a small risk of so-called bone cement implantation syndrome and a paper based on NJR data from McMinn et al. suggested that patients having cemented hip replacements had a higher risk of death than those having uncemented or resurfacing hip replacements. The authors were unable to conclude whether or not the association between fixation and mortality was causal or if it reflected residual confounding variables such as age, health status, geography, socioeconomic status and deprivation, many of which are not recorded by the NJR. Indeed, only about 19% of the variability in mortality can be explained by variables available in the NJR dataset. There are of course measures that can and must be taken to reduce the risk to patients when using cement and in an in-depth analysis of mortality after hip replacement Hunt et al. showed that there had been a significant fall in the rate of mortality after hip replacement, from 0.56% in 2003 to 0.29% in 2011. This paper looked at the NJR and Hospital Episode Statistics (HES) data of 409,096 patients and concluded that posterior approach, thromboprophylaxis and spinal anaesthetic were all associated with decreased mortality, but the type of prosthesis and its fixation were not related to the risk of mortality after hip replacement. The same authors have recently published an analysis of the main causes of death after hip and knee replacement. They compared causes and rates of mortality in the general population and in an age and sex matched cohort of over 300,000 THR patients. They found that THR patients had a reduced risk of mortality compared to the general population and this effect persisted for 7 years after the operation.

**Conclusion**

Cemented hip replacements continue to provide advantages to patients and surgeons that cannot be overlooked. Tried and tested designs offer the lowest rates of revision in almost all patients. Research and registry data show that they are safe, forgiving and reliable in the majority of surgeons’ hands and they come at a cost to society that is lower than uncemented...
components. Moreover, the flexibility that they offer, with independent control of offset, leg length and component position, mean that with cemented components it is easier for a surgeon to perform a hip replacement that is tailored to each patient’s needs. The flexibility that they offer extends out for the lifetime of the patient, with the option of cement-in-cement revision available should further surgery be required in a patient’s future. The numerous advantages that they confer underscore why I do cemented hip replacements.

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