Total Hip Arthroplasty: Using clinical performance to guide implant selection
Introduction

As the population ages and total hip replacement devices and materials continue to evolve, more young patients will undergo total hip arthroplasty (THA). There are numerous options available for both femoral and acetabular components, including the Pinnacle Acetabular Cup System and Corail Hip System (DePuy Orthopaedics, Inc.).

From results presented in 2007 involving 1,183 hips, the overall survival of the Pinnacle cup acetabular component was 99.9%.1 Updated results of this study (May 31, 2011) indicate an all cause (any component) survivorship of 96.1% at 8 years in 1,582 THAs with Pinnacle Cups.2 Importantly, there is data on the specific combination of Corail and Pinnacle. The Joint Registry from England and Wales showed that among 40,879 patients with a Corail and Pinnacle combination, the 5-year survival was 97.7%.3

Surgeons have 25 years of experience with the Corail stem. The Norwegian registry indicates greater than 97% survivorship at 15 years.4 In another study, the 10-year outcomes demonstrated low rates of aseptic loosening and a total reoperation rate below 3%.5

This supplement features studies and registry data related to Corail and Pinnacle THA components. I would like to thank the faculty members for their expertise, as well as DePuy Orthopaedics for sponsoring this ORTHOPEDICS TODAY Europe supplement.

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References
Modular acetabular cup system provides versatility and positive results

Kirk A. Kindsfater, MD

The Pinnacle® Hip System (DePuy Orthopaedics, Inc.) was the first cementless acetabular cup to feature a design allowing varying combinations of acetabular liners. Though other designs have since mimicked this approach, Pinnacle has been established as a class leader and an extremely reliable clinical device. Within my clinical practice over the past 10 years, I have implanted more than 3,000 of these acetabular cups, and I continue to use it for all total hip arthroplasty (THA) patients, both primary and revision.

The variable liner cup system allows surgeons to use Pinnacle on almost every patient that requires a THA. In older patients, for example, a polyethylene liner may be the most appropriate bearing choice. In high-demand patients, a hard-on-hard bearing (ceramic-on-ceramic, ceramic-on-metal, metal-on-metal [MoM]) may be the best choice. The variable liner cup also allows for simplified reoperations in the event a revision is required. In fact, there is no need to replace the entire cup when a liner can easily be switched out to accommodate other designs—lipped, lateralized or face-changing liners—in cases of instability. The Pinnacle Hip System uses Variable Interface Prosthesis taper technology to allow for multiple liner options. Additionally, Pinnacle enables me to refine a single surgical technique with which I am very familiar, and one that has provided consistently positive results for my patients. This has the potential to minimize any variability in outcomes that could be introduced by adopting different implant systems, which I would use less frequently, for different patients.

Clinical data and outcomes

The clinical data on Pinnacle suggest a device that rarely runs into problems.... 8-year survivorship of 96.1%.

— KIRK A. KINDSFATER, MD

Updated results of this study indicate an 8-year survivorship of 96.1% for revision of any component for any reason. For reference, the 5-year survivorship is 97.2%. The study included 1,582 primary THAs, performed across 17 surgeons, and involved nine different cemented and uncemented stems. This versatility suggests an implant that is highly adaptable to surgeon experience and compatible with varying surgeon stem philosophies. There were a total of 31/1,582 (1.6%) hips revised for any reason resulting from dislocations (13), deep infections (8), hip pain (1), femoral fractures (3), hematomas (1), adverse local tissue reaction (3) and stem loosening (2). In 10/31 (32.3%) instances the cup was retained and the liner was exchanged with another of the system’s options.

The mean Harris Hip Scores were excellent going from a preoperative score of 46 to a 1-year postoperative score of 95. The mean Harris Hip Scores remained high (range of 94 to 95) throughout 8 years postoperatively. The mean flexion scores were 89° preoperatively, and 101° throughout 8 years postoperatively. In the study showing 96.1% mid-term survival of the Pinnacle Acetabular Cup System, the cohort was split between the various liner options. Of the total 1,582 hips, 888 (56.1%) received a metal-on-polyethylene (MoP) bearing, 667 (42.2%) received a metal-on-metal (MoM) bearing, and the remaining 27 (1.7%) received a ceramic-on-polyethylene (CoP) bearing.

The MoM group reported 10 failures. Survivorship at 8 years is 96.3% (95 CI 91.8% to 98.3%) and at 5 years survivorship is 97.5% (95% CI 94.8 to 98.8%). The following reasons for revision were reported: dislocation (1), deep infection (4), pain (1), femoral fracture (1), and adverse local tissue reaction (3). Three revisions required removal of the Pinnacle Cup.
There were 21 failures reported in the MoP group, yielding an 8-year survival rate of 95.8% (95% CI 93.0% to 97.5%). Survivorship at 5 years is 96.9% (95% CI 95.0% to 98.1%). The following reasons for revision were reported: dislocation (12), deep infection (4), aseptic loosening of the stem (2), femoral fracture (2), and hematoma (1). There were no reports of revision due to lysis, wear, or liner disassociation. Seven revisions required removal of the Pinnacle Cup. There were no reports of revision in the CoP group.

Furthermore, the data on Pinnacle have remained consistently positive in a number of clinical publications, national joint registries and independent studies, similar to the one referenced previously. In another recent paper from the Mayo Clinic, results were reported from a comparative study on 9,584 acetabular cups over a 21-year period using data from the Mayo Clinic joint registry. The authors reported patient outcomes in terms of hazard ratios (risk) for revision, loosening and wear. Mid-term results on 236 Pinnacle standard polyethylene and 854 Pinnacle cross-linked polyethylene hips showed, overall, higher survivorship for both cohorts out to 8 years of follow-up, compared to other designs introduced after 1990. There were no cases of revision due to aseptic loosening, wear or osteolysis. The Pinnacle cross-linked polyethylene had the lowest risk of revision of either the cup and/or liner for any reason as compared to all other acetabular options except a small cohort of Implex implants, although the differences were not significant. Significant differences may still emerge with longer follow-up.

The success of the Pinnacle Hip System, based on various clinical sources, mirrors my own clinical experience. Among the 3,000+ Pinnacle cups I have implanted, I have had to perform reoperations on only four cups. Three were a result of surgical error (my own), with either too much anteversion on the cup or placement that was too vertical, resulting in impingement on the acetabular liner or edge loading of the liner. Two of these patients had polyethylene liners and one patient had a metal liner. The fourth patient with a MoM articulation developed ALVAL, or aseptic lymphocytic vasculitis-associated lesion, that required revision to a polyethylene liner.

Although complete follow-up is unavailable for all of my patients, I am unaware of any in my series of 888 patients with Marathon who have been revised for osteolysis or wear. Furthermore, since I began using the Pinnacle Hip System in 2001, the results have been positive and the vast majority of my patients have experienced good function with few, if any, problems (Figure).

The Pinnacle Hip System also offers a modular MoM insert that mates with the same shell. Although MoM bearings have fallen out of favor recently, I still use them in appropriate situations. I have had extremely good success with this modular MoM bearing. I have implanted more than 1,300 large diameter (36 mm or greater) Pinnacle MoM bearings in the last 10 years and have only revised two as a

**Figure:** Radiograph showing press fit total hip arthroplasty with S-ROM stem and Pinnacle cup.

*Source: Kindsfater KA*
result of problems with the bearing. Approximately 85% of these bearings have been 36 mm in diameter with most of the remainder being 40 mm, and a small percentage being 44 mm. Pinnacle’s modular bearing design seems to function differently than the jumbo-head/one-piece acetabular designs that have been prone to higher failure rates as of late. This is a complex problem due to many different variables including shell stiffness and thickness, deformation of the shells during insertion, clearance of the bearing, and the sub-hemispherical design of different shells.

The performance advantage of the Pinnacle modular metal liner is a result of many factors—some not entirely understood. However, I believe that the stiffness of the modular metal liner, the resistance of this liner to deformation and the ability to maintain an appropriate clearance of the bearing, are some of the more important factors that have led to the success of the Pinnacle modular MoM articulation.

Finally, registry data from the United Kingdom reinforce Pinnacle’s solid record. The most recent report from the National Joint Registry for England and Wales (NJR) showed that the most common cementless cup was the Pinnacle, at 34% of the total market. The most commonly used uncemented combination—Pinnacle and the Corail Hip Stem (DePuy)—yielded a 5-year survivorship of 97.7%, in more than 40,000 patients.

Surgical technique

For surgeons starting out with the Pinnacle Hip System, the learning curve is minimal, and the design of the shell and liner is such that positive head/neck ratios can be achieved, allowing for increased stability of the construct. I have used the posterior approach during my career and this approach has historically had a higher dislocation rate than the direct lateral or anterior approaches. However, my dislocation rate with Pinnacle is typically less than 1%, aided by the ability to use 36-mm diameter heads with desirable head/neck ratios, in the majority of my cases. In the past I tended to use as large a head as possible to assist in minimizing dislocation. Yet, recent literature suggests a benefit to be gained from a dislocation standpoint with increasing head size up to 36 mm in diameter. However, it is still comforting to see these large heads in situ given the jump distance to dislocate the head is quite large. Therefore, I still use as large a head as possible against polyethylene. Recently, I began using 36-mm heads, even with larger shells, when implanting MoM bearings. I have had such success with this size bearing over the past 10 years that I feel more comfortable with the 36-mm head versus the 40-mm, or even 44-mm heads, for which I do not have such long-term follow-up.

The surgical technique itself is, again, similar to other devices and easy for surgeons to master. The technique that I have used successfully in more than 3,000 implanted Pinnacle shells is to ream 1 mm less than the cup I plan to implant. I typically use a shell trial that is 2 mm smaller than the cup I will be implanting. This allows me to gauge the fit of the final shell without enlarging the acetabular cavity that I have just prepared. This provides me with a reproducible 1-mm press fit when the final shell is implanted. I have found this to provide excellent press fit of the shell in almost all cases. Using this technique I am able to place approximately 80% of shells without supplemental screw fixation.

Surgeons preparing to use the Pinnacle Hip System need to be cognizant that all systems’ acetabular components are not sized similarly. For instance, if surgeons have been using a system in which the shell is oversized by 1 mm, they may be accustomed to reaming line-to-line before implanting their final shell. Pinnacle, in contrast, is true to its description and sizing information. The surgeon should know the true nominal diameter of the shell to be implanted to decide how much to under-ream prior to placement of the final shell. The technique I have described above has worked well in almost all of my cases with Pinnacle.

Surgical options

The Pinnacle Hip System offers three primary cup options that include a no-hole (100 series), a cluster-hole with three grouped screw holes (Sector) and a tri-spike cup (300 Series). Polyethylene liner options include standard offset, +4 lateralized, 10° face changing, lipped and constrained. For revision THA patients or atypical primary patients where the bone has been compromised, I tend to use the Pinnacle multi-hole or revision shell with Gription® porous coating (DePuy). This coating has a higher coefficient of friction than standard Porocoat® porous coating (DePuy), and has the potential to provide better initial fixation when the bone is compromised. The fixation surface of Gription maintains
a 63% porous, 300-micron pore structure, and has demonstrated a coefficient of friction of 1.2 in lab testing. This represents an improvement over standard porous coating. In some patients I choose not to use a Gription shell, because its high friction can sometimes make it slightly more challenging to insert than a traditional Porocoat shell.

As one of its revision cup offerings, Pinnacle has a deep profile (DPx) option that is useful for revisions where a protrusio deformity is encountered or where lateralization of the center of rotation is required. The Pinnacle revision cup has a thicker shell that allows for additional fixation in the form of rim screws.

Preoperative planning and templating for Pinnacle is straightforward and similar to other devices. Radiographs help determine the size of components needed. If there is substantial bone loss or other factors that could complicate the procedure, then appropriate implants such as Gription porous-coated revision shells—standard or deep profile—can be used.

In my opinion, one of the key advantages of Pinnacle is its adaptability to my patients’ morphological requirements, especially in difficult or revision cases where many intraoperative options might be required. The Pinnacle Hip System can comfortably handle most situations that will be encountered.

Postoperatively, the initial fixation of the Pinnacle cup allows full weight-bearing for almost all patients. I typically allow my THA patients to reduce dependence on assistive devices as tolerated. Usually at 3 months postoperative I allow patients to return to normal activities without significant restriction.

**Conclusion**

The Pinnacle Hip System has proven to be an extremely reliable and successful option for THA with more than 10 years of clinical experience. To date there have been more than 1 million Pinnacle shells provided to patients worldwide, with extremely positive results. Both patients and surgeons can feel comfortable that the most appropriate option for each situation will be available within one system. Finally, the mid-term clinical results reported on this system should give surgeons confidence that survivorship of this implant will meet their expectations.

**References**


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**TAKE-HOME POINTS**

- Pinnacle’s modular shell design allows varying combinations of bearing surfaces, making it a versatile option for virtually all patients undergoing THA.
- Revision rates for Pinnacle are extremely low in a number of independent studies.
- MoM bearings, though controversial, have yielded excellent results with the Pinnacle Hip System.
- For surgeons starting out with the Pinnacle Hip System, the learning curve is minimal.
Up to 10-year results show promise for tapered titanium implant

Mark Froimson, MD, MBA

Patients and surgeons have a number of implant options for total hip arthroplasty (THA). Differences in design can affect both the ease of the surgical procedure and the clinical outcomes. Among the most commonly used uncemented THA implants is the Corail® Hip System (Depuy Orthopaedics, Inc.). Although introduced in Europe in 1986, Corail entered into widespread use in North America following FDA clearance in 1998. The device is now celebrating its 25th overall year with an unchanged intramedullary design, providing long-term data on its clinical performance. These data suggest that it is one of the most reliable implants on the market today providing a durable construct that is unsurpassed.¹

Experience and data

In North America, due to its adoption nearly 15 years ago, intermediate-term results with the Corail are now available at an increasing array of arthroplasty centers. Results to this point have been promising and are generally quite consistent with those previously reported. The Cleveland Clinic has 10-year data on 169 hips implanted in 158 patients, and the University of Pennsylvania in Philadelphia has 10.5-year results from an additional 188 hips in 170 patients.₂ Overall, these patients ranged in age from 31 to 90 years, with women accounting for 46% of the total cohort; 85% of these patients underwent total hip replacement because of osteoarthritis.

Patients followed a modern, rapid recovery protocol and were allowed full weight-bearing on the day of surgery, and were generally discharged on day three. After at least 10 years of follow-up, there have been no cases of aseptic loosening or failure of fixation. A total of nine patients required reoperation: three had all components removed due to infection, three had acetabular revisions with retention of the femoral component due to acetabular osteolysis, and three cases were revised for instability.

Taken in total, these two cohorts yielded a 10-year survival rate of 100% for lack of aseptic loosening, 99.1% for stem retention and 97.7% with no reoperations. This degree of success is consistent with data in Europe, where the Corail has been in use for up to 25 years. One report from the ARTRO group, who originally introduced the Corail in 1986, found 98.3% survivorship out to 14 years.¹

The Norwegian National Joint Replacement Registry provides a second, and arguably more objective, source of long-term performance of this implant.³ In an analysis of 11,516 hips in 9,679 patients in whom 14 different uncemented stem designs were used, the Corail implant was used most frequently (5,456 hips) and, more importantly, most successfully. Overall, although many stems performed well with regard to aseptic loosening at the 10-year interval, by 15 years there was substantial differentiation of success rates. In this cohort the 15-year survivorship of the Corail stem for any reason was 97%. When studying factors that impact implant survivorship, researchers found that age and diagnosis had no effect on survival of the implant, but male gender was associated with increased revision risk.

Registry data in the United Kingdom and other published papers that have reported clinical follow-up of THA cases using the Corail Hip System have both shown similarly promising results (Table, page 8).¹⁻⁶
For example, the National Joint Registry for England and Wales reported a 97.7% survivorship at 5 years (n=40,879) for the Corail Hip System when used in combination with the Pinnacle Acetabular Cup System.4

Design of the Corail

The success of this implant is a result of both an innovative design and an easy, reproducible insertion technique. The Corail Hip System, made of a titanium-substrate, uses a triple-tapered design, tapered in the anterior-posterior (AP) dimension and from lateral to medial.7 The stem features grooves both in the horizontal and vertical directions, intended to increase both rotational and axial stability after implantation.

The stem is coated with a proprietary hydroxyapatite (HA) layer of approximately 155 µm thickness. The combination of the macro-structure—tapering, and horizontal and vertical grooves—and the HA coating were designed to promote implant stability.

The Corail can be implanted with either a collarless or collared stem, depending on surgeon preference and estimations of bone quality. The collarless feature allows for optimal endosteal contact, but patients with osteopenic bone can derive additional stability and reduced subsidence with a collared stem.1,5 The design of the extra-osseous portion includes varying neck angles and offsets, as well as the Articul/Eze® taper and polished neck, to increase range of motion and reduce the risk of impingement and wear debris generation.7

This full coating with HA has been shown to yield excellent results. One study of bone response to the implant evaluated 245 patients (291 hips) implanted with the Corail for a mean of 10 years, and found a small amount of proximal bone loss (37/291) as well as a low incidence of distal hypertrophy (23/291 hips). The investigators concluded that the changes in bone confirmed that the femoral component of the implant was well fixed.8

Preoperative planning

Preoperative planning, including templating, determining leg length and potential discrepancy, assessing acetabular component size and placement, will ensure that the surgeon has optimized his chances for a successful implantation.9

Before implantation, the surgeon should perform a clinical evaluation in conjunction with a radiographic analysis to determine preoperative leg length discrepancy and use both to determine intraoperative leg length management.

Second, the surgeon should assess acetabular component size and placement. Most sizing determinations are made using the AP radiograph of the hip. The stem comes in 1-mm size increments and the tapered geometry allows for different sizes to seat at different depths. Therefore, the size and depth of insertion must both be assessed. In addition, there are several offset options that allow for recreation of the hip center and femoral offset. It is therefore possible for the surgeon to determine which option restores proper offset by

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Table. Reported Survivorship for the Corail Hip System

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<th>Author</th>
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<th>Number of Hips</th>
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<th>10 Years</th>
<th>12 Years</th>
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<td>France</td>
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<td>—</td>
<td>—</td>
<td>99.1%</td>
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<tr>
<td>National Joint Registry of England &amp; Wales4</td>
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<td>—</td>
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<td>97.6%</td>
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Source: DePuy Orthopaedics, Inc.
matching the cup’s center of rotation with the desired head center of rotation.

**Surgical technique**

The ease with which this implant can be inserted allows for virtually any exposure to be used. In fact, I have found that the Corail can be very conducive to smaller incisions or newer exposures.

Following femoral neck osteotomy, the femur is easily prepared for the Corail. It can be done prior to or following acetabular preparation. I prefer doing it immediately after osteotomy, because the anteversion of the flat femoral component can be set and noted, after which the acetabular version can be modified, if necessary. In addition, with the femur exposed for the osteotomy, the preparation of the canal takes just a few additional minutes and the trial broach can be left in place for trial reduction attempts as needed. The implantation depth can be assessed and the sizing adjustments made, if necessary, should limb length concerns require the implant to be seated at a different depth. This can be accomplished by downsizing or upsizing as indicated.

Femoral preparation follows a technique known as compaction broaching, allowing for the preservation of all cancellous bone within the femur (Figures 1 and 2). Compaction broaching involves compressing the softer cancellous bone within the femur into the outer shell of bone. A surgeon who transitions to using the Corail will have to slightly adapt his/her surgical technique and may have a desire or tendency to try to push to a larger size implant than necessary, but the learning curve is minimal. The macro design features—tapering and grooves—allow for a generally smaller implant than with other options, and often a smaller size than was templated. This is due to the addition of the compacted cancellous sleeve to the endosteum, functionally diminishing the size of the canal. The initial axial stability provided by the horizontal grooves lowers the risk of subsidence within the bone. The procedure is remarkably bone sparing, because there is virtually no bone removal required beyond the arthritic head itself.
The HA coating and macrostructure of the Corail provide a high friction, rough surface that quickly engages the canal on contact. In addition, the actual implant, with its coating, is larger than the broach and will get a firm interference fit. As such, in most bone types, but particularly in type A and B in my experience, the implant will engage rather rapidly and will not advance as far as other systems. Consequently, a good rule of thumb is to ensure that the implant is inserted by hand to within 1 to 1.5 cm of the desired position prior to impacting it. The bone-preserving design of the Corail may allow for a smaller implant than expected to achieve stability, and thus surgeons should be careful not to use an oversized implant; this can lead to the implant sitting too proud by a few millimeters, and thus the patient’s leg may end up too long and obviously decrease patient satisfaction. One consideration is to build the hip to accommodate a medium or mid-range neck, so that the final position can be accommodated with adjustment to neck length up or down.

The Corail is indicated for a wide variety of total hip replacement candidates, although there are some exceptions. Patients with significant deformity, including significant alterations to femoral head anteversion, may need a modular implant, because there is a limit to the variation in anteversion that can be achieved with a nonmodular flat stem. Corail is appropriate, however, for well over 95% of my THA patients.

**Patient satisfaction**

In my experience, patient satisfaction with the Corail has been extremely good, based on the immediate recovery after implantation and the ability to return to high function. There appears to be very little trauma to the endosteum and less pain than occurs with reaming of the canal. This generally acceptable level of postoperative pain allows patients to be comfortable very quickly following implantation. They also begin walking almost immediately postoperatively. As patients return to regular activity, satisfaction has also been high, with the physiologic load of the implant allowing patients to return to a wide array of activities. Patients in our cohort include avid tennis players, skiers, hockey players and horseback riders, to name a few. At intermediate-term follow-up of these patients, there is no deleterious impact of activities on bone remodeling, and survivorship does not appear to be compromised. Fixation achieved with this implant is not the limiting factor for longevity. Whether bearing advances can allow patients the freedom to pursue their activities of choice over the long term remains to be seen.

**Conclusion**

Based on our clinical experience over more than a decade with this device, I have found it not only reliable for my patients, but very easy to teach to other surgeons who want to adopt it into their own practices. In addition, the operating room staff find the instrumentation easy to use and simple to set up, increasing operating room efficiency and reducing set up time. Most importantly, it is a very reliable and versatile

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**TAKE-HOME POINTS**

- Corail stem has 25 years of positive experience, making it one of the most reliable THA implants.
- 10-year results show virtually no cases of aseptic loosening, and total reoperation rates below 3%.
- Registry data from Norway and elsewhere are also extremely positive, with 15-year results indicating greater than 97% survivorship.
- Triple-tapered design increases stability after implantation.
- Pain and postoperative recovery of function are excellent with the Corail, leading to high patient satisfaction with this device.
implant that has proven successful over a wide array of patient and bone types. The durability of the construct is apparent, because the quality of the bone at intermediate-term follow-up remains quite robust, with very little evidence of stress shielding or adverse bone remodeling. Revisions have been few, driven exclusively by infection, dislocation, and osteolysis associated with bearing materials. There have been no cases of aseptic loosening.

Overall, our experience with the Corail Hip System has been very positive to this point. Patients routinely note good experiences perioperatively with rapid recovery and short hospital length of stay associated with manageable postoperative pain and reliable return to activities. Restoration of anatomy allows for reliable function based on appropriate kinematic reconstruction. The success stories of our patients are common, and as experience with the implant grows so has our confidence in its ability to deliver for a wide array of patients with varying degrees of bone quality.

References:

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