Femoral Component Fixation in the 1990s

POROUS-COATED FIXATION: A RITE OF PASSAGE

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Porous-coated femoral components have been used in the United States for over 15 years. Fixation of these implants occurs when a combination of bone and fibrous tissue grows into the porous surface. With time, this new connecting bone hypertrophies, firmly fixing the porous surface to the femoral cortices. This fixation method was developed as an alternative to cement fixation. The rationale was that if bone grew into the porous surface, the bond would be stronger and more durable than that which can be accomplished with polymethylmethacrylate bone cement.

In my opinion, there are three requirements for consistently achieving bone ingrowth fixation of a femoral component:

- the implant must have an extensive amount of porous coating available for bone ingrowth fixation (i.e., >50% of the stem surface should have this porous coating);
- the porous surface must be on the portion of the implant which is most likely to be in direct contact with the viable cortical bone; and
- the cortical bone that directly contacts the porous surface should be strong enough to support the implant when body weight is applied to the prosthesis.

Since the internal dimensions of the femoral metaphysis and the proximal portion of the intramedullary canal vary from case to case, the porous-coated implants must be made in many sizes to achieve these three fixation requirements. In addition, the instrumentation for insertion of the implants should allow the internal shape of the femur to be modified to more accurately match the shape of the implant.

Not all first-generation, porous-coated femoral implant systems fulfilled these fixation requirements. Those that did not often produced unsatisfactory results because biological fixation into the porous surface did not occur consistently. The characteristics of these less successful implants included:

- an inadequate amount of porous surface, or the application of the porous surface to an area of the implant which could not easily be placed in direct contact with cortical bone;
- poorly sintered porous surfaces; and
- porous surfaces which recessed within the implant in limited areas (usually flat surfaces on the upper portion of the implant).

These recessed surfaces were also less likely to come in direct contact with cortical bone. Furthermore, implants that lack a circumferential proximal porous coating are considered less satisfactory than implants with circumferential coating because they do not seal off the joint space from the intramedullary canal. These implants are more prone to osteolysis around the tip of the prosthesis than implants which do have a circumferential porous coating.

Other first-generation, porous-coated implants have produced excellent results. Figure 1 illustrates several porous-coated implants which I consider to have desirable design features. All have an extensive porous surface, a relatively simple geometric shape (which facilitates intramedullary canal preparation to match that shape), and circumferential porous coating that has not recessed below the stem surface. The Table includes the intermediate-term (5- to 10-year)
Table

<table>
<thead>
<tr>
<th>Author</th>
<th>Design</th>
<th>Design Features</th>
<th>No. of Hips</th>
<th>Follow Up</th>
<th>Revision for Aseptic Loosening</th>
<th>Unstable, Unrevised</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lachiewicz et al (1992)</td>
<td>Harris-Galante</td>
<td>Ti-straight stem, CP-Ti fibremesh pads</td>
<td>100</td>
<td>2-5 years; mean, 37 months</td>
<td>1%</td>
<td>0%</td>
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<tr>
<td>Galante &amp; Jacobs (1992)</td>
<td>Harris-Galante</td>
<td>Ti-straight stem, CP-Ti fibremesh pads</td>
<td>121</td>
<td>3-6 years; mean, 67 months</td>
<td>3.6%</td>
<td>9%</td>
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<tr>
<td>Galante et al (1994)</td>
<td>multilock</td>
<td>Ti-straight stem, CP-Ti fibremesh coating (circumferential)</td>
<td>176</td>
<td>mean, 2 years</td>
<td>0%</td>
<td>0%</td>
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<tr>
<td>Dorr et al (1994)</td>
<td>APR-I</td>
<td>Ti-curved stem, cancellous patch porous coating</td>
<td>100</td>
<td>5-9 years; mean, 7 years</td>
<td>9%</td>
<td>1%</td>
</tr>
<tr>
<td>Dorr et al (1994)</td>
<td>APR-II</td>
<td>Ti-curved stem, circumferential, cancellous porous coating</td>
<td>162</td>
<td>2-5 years</td>
<td>0.6%</td>
<td>0.6%</td>
</tr>
<tr>
<td>Heekin et al (1993)</td>
<td>PCA</td>
<td>CoCr curved stem, sintered beads</td>
<td>100</td>
<td>5-7 years</td>
<td>1%</td>
<td>5%</td>
</tr>
<tr>
<td>Engh et al (1994)</td>
<td>AML</td>
<td>CoCr, straight stem, sintered beads, extensively coated</td>
<td>166</td>
<td>6-13 years; mean, 41 months</td>
<td>0.6%</td>
<td>1.8%</td>
</tr>
<tr>
<td>Capello (1994)</td>
<td>Omniflex</td>
<td>Ti-straight stem, Ti bead, modular hydroxyapatite coated, straight stem</td>
<td>88</td>
<td>2-5 years</td>
<td>3.4%</td>
<td>6.8%</td>
</tr>
<tr>
<td>D'Antonio et al (1994)</td>
<td>Omnific</td>
<td>Ti-straight stem, Ti beaded spout, modular plasma sprayed</td>
<td>436</td>
<td>3-5 years</td>
<td>0.46%</td>
<td>0%</td>
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<tr>
<td>Cameron et al (1994)</td>
<td>S-Rom</td>
<td>Ti-straight stem, plasma sprayed</td>
<td>48</td>
<td>2-6 years</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Mallory &amp; Lombardi (1994)</td>
<td>Mallory-Head</td>
<td>Ti-straight stem, plasma sprayed</td>
<td>121</td>
<td>mean, 6.7 years</td>
<td>3.3%</td>
<td>0%</td>
</tr>
</tbody>
</table>

Results for many of the first- and second-generation, porous-coated implant systems. The revision and loosening rates reported for some of these implants are as good or better than the best results reported with other fixation techniques at comparable time intervals. The AML femoral prosthesis is the only first-generation, porous-coated prosthesis that has porous coating extending into the femoral diaphysis. I prefer this design because I depend on a tight diaphyseal fit of the implant, both for primary stability and secondary fixation by biological ingrowth. I prefer that the part of the implant designed to fit the femoral diaphysis be straight, cylindrical, not tapered, and fully porous-coated. The AML stem fits these criteria.

At the time of surgery, I drill the femoral diaphysis to a matching shape. I am confident that I am obtaining the maximum amount of porous coating in contact with the resharpened endosteal surface. This same technique can be used to insert a proximally porous-coated implant, but the result will be less porous surface in direct contact with the endosteal cortex. Figure 2A, for example, shows a proximally porous-coated implant of the AML design with a tight diaphyseal fit. The porous coating on the proximal portion of this implant is not in contact with the cortical bone that is supporting the implant. In contrast, the completely porous-coated AML implant shown in Figure 2B has a much greater amount of the porous surface area in direct contact with the bone supporting it.

CONCLUSION

My goal with a porous-coated stem is to achieve as much bone ingrowth as possible. This is accomplished by using a stem with porous coating over its entire surface. I accept the fact that when the entire stem is porous-coated, the greatest amount of bone ingrowth will occur in the femoral diaphysis. Figure 3

![Image: Examples of currently popular porous-coated femoral prostheses.](image-url)

Fig 1: Examples of currently popular porous-coated femoral prostheses.
Fig 2: Immediate postoperative radiographs of femurs containing an AML stem. Proximally porous-coated (A). Fully porous-coated (B).

Fig 3: Scanning electron micrograph of expected distal femoral bone ingrowth with the AML stem.

shows a transverse section through the diaphysis of one of my cases; this is the desired fixation result. When this type of biological fixation occurs, a predictable pattern of femoral bone remodeling also results. This bone remodeling includes proximal cortical bone resorption and endosteal densification near the termination of the porous coating on the implant surface. This pattern is illustrated in Figures 4A-B. I find this change in the radiographic appearance of the femur desirable because it indicates that osseointegration of the stem has been successful.

I predict that femoral implants which have porous coating into the diaphysis, such as the AML (DePuy, Warsaw, Ind), will continue to gain popularity for several reasons: First, the surgical technique is easy to perform correctly. Second, when the surgical procedure is done correctly, the likelihood of achieving radiographic evidence of bone ingrowth is >98%. There will be a few cases in which the radio-

Fig 4: Immediate postoperative (A) and 2-years' postoperative (B) radiographs of a femur containing an AML prosthesis. The change in the bone's appearance indicates that bone ingrowth has occurred.
graphs indicate that bone ingrowth fixation has not been achieved, but in these cases, revision is not difficult. The loose prosthesis is easily removed, the intramedullary canal can then be redrilled, and a larger implant with more porous coating can be put in with a tighter fit. Most importantly, in cases in which the radiographs show that osseointegration has been successful, the likelihood of late failure due to loosening is extremely low. I have used extensively coated implants in several thousand cases in the past 15 years. I request of all of my patients that they return for annual follow-up radiographs. To date, I have not seen a single case in which a bone-ingrown prosthesis has failed due to loosening.

REFERENCES


