Among the many controversies concerning cemented total hip arthroplasty, few have given rise to more discussion in orthopaedic journals and textbooks than the desirable thickness of the femoral cement mantle, a subject addressed by the paper of Skinner et al in this issue of the Journal (see p 45). Conventional wisdom in non-Francophone countries is based mainly on the results of theoretical and laboratory work\(^1\)\(^-\)\(^7\) supplemented by clinical studies\(^8\)\(^-\)\(^12\) and analysis of retrievals at post-mortem.\(^13\)\(^,\)\(^14\) All suggest that the mantles should have a minimal thickness of 2 to 4 mm, and should, moreover, be complete. The supposition is that when the mantles fail to match these requirements, mechanical failure of the cement from fatigue may ensue and may progress to femoral lysis with loosening of the implant.

This perceived wisdom is challenged by the article of Skinner et al, and to a much greater extent by the ‘French paradox’, the term applied by one of the authors (FL) of this annotation to the apparently paradoxical results obtained with two French-designed cemented femoral components, the Charnley-Kerboull\(^15\) and the Ceraver Osteal,\(^16\) which are both intended to occupy fully the medullary canal of the femur. With these designs the views which have been generally accepted in non-Francophone countries regarding the thickness of the cement mantle have been entirely transgressed. Also, with the Charnley-Kerboull design, the recommended operative technique involves the complete removal of all cancellous bone in the medullary canal before the insertion of cement.\(^15\) Many non-Francophone surgeons would regard this combination as a recipe for failure, yet the results in the medium and long term have been excellent. These findings have profound implications for the behaviour of acrylic cement in the femoral canal in vivo, and for the mechanisms which underly aseptic loosening of the stem.\(^17\)

The design philosophy of these stems implies that the cement mantles will be very thin. Since both stems are straight and the femoral medullary canal is not, the mantles may not only be thin, but sometimes incomplete in places. These points are emphasised by published descriptions of the designs and operative techniques. Thus, Kerboull\(^15\) wrote: “To ensure that the prosthesis was still aligned, that no cancellous bone remained at the compression zones, and that the cement was not subjected to forces that it could not withstand, the simplest solution seemed to be to completely empty the medullary canal of cancellous bone and to force in a well-fitting prosthetic stem that would almost completely fill the medullary cavity prior to the addition of cement”. Similarly, Witvoet\(^18\) described the operative technique used with the Ceraver Osteal stem: “On a technical level, we try to fill the medullary femoral canal as much as possible with the largest possible stem, which requires boring of the medullary cavity in a number of cases..... We do not try to obtain a continuous cement mantle”. These stems require hammer blows to complete their insertion.\(^19\)

Partly because of their rectangular cross-sections, both stems have substantial intrinsic stability within the medullary canal, especially in torsion, even in the absence of cement. Excellent results with stem survivorship better than 99% at ten years have been reported with the Ceraver Osteal stem when used with alumina-on-alumina bearings\(^16\)\(^,\)\(^20\) or alumina-on-polyethylene.\(^21\)\(^,\)\(^22\) With the former,\(^16\) focal femoral lysis was seen in 3% of cases but only occurred in association with migration of the socket. Interestingly, Hernigou\(^21\) reported that the results were less good, with 2% showing aseptic loosening with increased radiolucent lines, when there was “...poor filling of the diaphysis by the implant,” a finding which complements those of Skinner et al. The Ceraver Osteal stem has always been manufactured from anodised Ti6A14V, with a surface roughness of 0.08 µm (3.2 µin) (a polished surface) and a large collar. By contrast, the Charnley-Kerboull stem has had a number of dif-
different versions (Table I), all manufactured from stainless steel and in all of which the collar has been small medially as with the original Charnley, but larger anteriorly and posteriorly. The best results have been achieved with the polished versions of the stem with rectangular cross-sections (Table I). A version of this stem made of Ti6A14V was unsuccessful.

A third French stem, the Fare, manufactured by ICP, Chaumont, France, from Ti6A14V, is: “a curved design with a small collar and a neck-shaft angle of 135°. It is oval in cross section to maximise the fit and fill of the femoral medullary canal”.23 Unlike the Ceraver Osteal, however, this stem was initially manufactured with a rough surface, being originally sand-blasted. Subsequent versions were bead-blasted and the latest version polished. There was a threefold increase in failure of the stem and formation of granulomas in prostheses with the rough-surface finish.23

These results should give all orthopaedic surgeons and bioengineers involved in cemented total hip arthroplasty much food for thought. They do not, of course, mean that bioengineers involved in cemented total hip arthroplasty necessarily have to abandon canal-filling stems. Therefore this effect may be magnified, and further work on this topic would be justified.

The intrinsic stability of these stems within the femur suggests that they may protect the cement mechanically, even although their polished surfaces mean that they are ‘debonded’ from the cement. The polished, double-tapered Charnley-Kerboull stem is believed to impose mainly compressive loads on the cement,15 especially since the latter is primarily supported by cortical bone. However, it seems unlikely that the Ceraver Osteal stem, with its large collar, could behave in the same way.

It is probable that the vigorous insertion of a canal-filling stem into doughy cement produces a marked increase in the pressures at the cement-bone interface which are achieved during insertion of the stem. Thus a stronger initial mechanical interlock at the cement-bone interface is obtained. In a canal from which all cancellous bone has been removed, however, only macrointerlock is possible at the cement-bone interface. It is uncertain to what extent there may be direct transmission of load from the polished stem to bone in areas where the mantles are incomplete. There are no published reports describing the histology at the long-term cement-bone interface in relation to these canal-filling stems, but whatever is happening in the femur at the histological level is clearly very benign.

It is impossible not to be impressed by the influence of the surface finish of the stem (Table I) on the outcome of these implants. The Ceraver Osteal has always had a polished surface. With the Charnley-Kerboull and Fare23 stems, the best results have been achieved with the polished surfaced versions. Those with a rougher stem have fared worse. At revision for loosening of matt-surfaces Charnley-Kerboull stems, failure was generally found at the cement-bone interface,27 raising the possibility that the increase in the shear strength of the stem-cement interface associated with the rougher stem surfaces had overloaded the cement-bone interface, a phenomenon originally suggested by Gardiner and Hozack28 almost a decade ago.

### Table I. Details of the various versions of the Charnley-Kerboull stem

<table>
<thead>
<tr>
<th>Name</th>
<th>Manufacturer</th>
<th>Date</th>
<th>Geometry</th>
<th>Surface finish</th>
<th>Loosening</th>
</tr>
</thead>
<tbody>
<tr>
<td>CK mark I</td>
<td>Benoist-Giraud Howmedica - now Stryker</td>
<td>1972-87</td>
<td>Rectangular double taper</td>
<td>Polished</td>
<td>1% to 2% ASL* at 20 years²⁷</td>
</tr>
<tr>
<td>CMK mark II</td>
<td>Sanortho - now Smith &amp; Nephew</td>
<td>1984-99</td>
<td>Oval in metaphysis round in diaphysis double taper</td>
<td>Matt: Ra = 0.6 to 0.8 µm (24 to 32 µm)</td>
<td>4% ASL at 15 years⁴¹</td>
</tr>
<tr>
<td>CK mark II</td>
<td>Benoist-Giraud Howmedica - now Stryker</td>
<td>1987</td>
<td>Rectangular double taper</td>
<td>Polished</td>
<td>0% ASL at 10 years²⁷</td>
</tr>
<tr>
<td>CMK mark III</td>
<td>Vecteur Orthopaedic</td>
<td>1988-97</td>
<td>Oval in metaphysis round in diaphysis double taper</td>
<td>Rougher than CMK mark II: Ra = 1.7 µm (67 µm)</td>
<td>21% ASL at 10 years</td>
</tr>
</tbody>
</table>

*aseptic loosening of the stem
There is, however, another possible reason why surface finish has apparently had such a pronounced influence on the outcome of these stems. Radiostereometric analysis (RSA) of non-canal-filling stems 29-31 has indicated that all stems, irrespective of their design or surface finish, migrate within the cement mantle during the first two years. Although there are no published RSA studies of canal-filling stems, there is no reason to suppose that they would behave differently. The polished surface allows the stem to move inside the cement mantle without damage to the latter and without affecting the cement-bone interface. With polished stems, the morphology of the wear changes produced by the cyclical movements of the stem against the cement associated with activities of daily living, shows that the wear mechanism is due to fretting. 32,33 This produces subsurface pits on the stem and does not damage the cement. By contrast, stems with a surface roughness greater than approximately 0.35 μm (14 μm) wear by an abrasive mechanism which sacrifices parts of the inner surface of the cement mantles that may, in turn, lead to torsional destabilisation of the stem within the cement, as well as to the production of large amounts of particulate debris. 32,33 A similar influence of surface finish is also seen with systems which do not fill the canal with cement. 34-39

There can be no doubt that these French stems, provided that their surfaces are polished, function well in the medium and long term, even although the cement mantles are extremely thin and may be incomplete. Better understanding of their function may come from RSA studies using techniques which can identify the interfaces at which migration occurs, and by histological studies of post-mortem specimens of hips known to have functioned well during life. It is interesting that the change from the polished, rectangular Charnley-Kerboull mark I stem to the matt-surfaced CMK mark II stem with rounded sections was instigated by fashion and the promptings of engineers, on the basis that the change in design and surface finish would render the cement less likely to fracture. It seems that surgeons should take what engineers tell them with some reservations and it may be that the fundamental role which is usually ascribed to mechanical fatigue failure of the cement in the genesis of aseptic loosening of the femoral component has been overstated. This view is supported by the predictive value of RSA during the early months following implantation in identifying those components which are later destined to fail as a consequence of aseptic loosening. 40

For obvious reasons, three of the four authors of this annotation believe that the use of the word ‘paradox’ in describing the behaviour of these implants is itself paradoxical!

References


