Cementless femoral fixation in total hip replacement (THR) has evolved from an experimental method of achieving satisfactory direct bone–implant interface in the 1980s, to the predictable and reproducible technique that has been available over the last ten years. In the United States, cementless femoral fixation is the method of choice in primary THR. Proponents of uncemented femoral implants espouse the concept of a direct interface between bone and the implant, believing it to be more durable against osteolysis, and so contribute to greater THR longevity. The technique is also simpler and potentially more reproducible than that of cement fixation, which requires multiple steps, each of which may introduce a source of error and lead to early failure.

There has been an evolution in cementless THR design since it was first used; materials, shapes and surgical techniques have changed. This paper will examine some of the design features that distinguish particular stems and may contribute to clinical differences. Two major designs have been popular and successful in the United States over the past 30 years: a proximally coated, tapered titanium stem, and an extensively coated, cylindrical, cobalt–chromium design (Fig. 1). Implant survival rates of over 95% at 20 years have been reported for both designs. Any distinction between these two must therefore be made based on other factors including the quality of the result, incidence of thigh pain, degree of stress shielding, ease of stem insertion, operative complications, and the ability to revise any failures. In addition, the stems must be judged on their ability to accommodate differing patient shapes and sizes.

### Materials
Cementless stems were initially constructed from cobalt–chromium alloys, which accommodate the application of circumferential porous coating throughout the majority of a stem surface. However, it was eventually appreciated that a stem of cobalt–chromium is extremely stiff, particularly when compared with cortical bone, and was leading to a relatively high incidence of post-operative thigh pain and stress shielding of the femoral shaft.

Titanium, with its lower modulus of elasticity, is somewhat closer to the stiffness of bone, and its use in uncemented stems has resulted in a lower incidence of thigh pain and stress shielding in many studies.

### Ingrowth surface
When cementless fixation was first developed, implants were extensively coated with a porous surface to provide the greatest potential for initial interference fit, stability, and subsequent bone ingrowth. Because the original stems were cylindrical, the technique proved simple and reproducible with straightforward reaming, broaching, and stem placement with 4 cm to 6 cm of press fit. Although this fully porous-coated designs did achieve the goals of initial fixation, the negative consequence of the distal fit was stress shielding of the proximal femur. Without any future revision surgery, stress shielding may not pose any risk. However, if revision surgery is subsequently required, it is understandably more difficult to work with...
reduced bone proximally. An extensively coated stem can be extremely difficult to remove, making an extended trochanteric osteotomy mandatory for extraction, along with sectioning the metal stem\(^\text{10}\) and removing the distal ingrown segment with hollow mill reamers. This can lead to bone necrosis, which can compromise the success of the subsequent revision procedure. The extensive reaming required for revision of these porous stems removes more bone than is necessary and can be performed eccentrically with the risk of peri-prosthetic diaphyseal fractures.\(^\text{11}\)

The alternative to a fully porous-coated stem is one that is only proximally coated and distally tapered. This may be inserted with a combination of reaming and broaching. Because these stems do not rely on a distal press-fit, they allow for the stem tip to be off-centre distally without risk of cortical compromise. This minimises ‘end of stem’ pain, as well as fracture risk. Such a proximal coated stem loads the bone more proximally and leads to less stress-shielding.\(^\text{7}\) It is also easier to remove, often only requiring disruption of the proximal bone-implant interface with fine osteotomes.

**Stem shape**

The earlier generation of tapered, titanium stems took a relatively long and straight form, requiring a more lateral canal entry to ensure placement centrally within the medullary canal (Fig. 2). These stems inevitably required more canal reaming, in order to accommodate the long distal length of the stem, which in turn made any revision more difficult.

Later generations of tapered titanium stems are shorter and less round. They are generically referred to as ‘flat, wedge-type’ stems, due to their propensity to fit tightly at the metaphyseal–diaphyseal junction (Fig. 3). In addition, many of these stems have an angular profile laterally, which preserves the bone and allows for ease of insertion while lowering the risk of trochanteric fracture. Because the distal part of the stem is thin and flat, no reaming is necessary; this simplifies bone preparation, speeds up surgery, and facilitates the use of smaller surgical approaches.

**Complications**

It has been estimated that approximately 1% of patients having a cementless femoral stem will have a fracture within two days of the surgery and up to 5% of patients can experience a femoral fracture within the first year.\(^\text{12}\) Even hip specialists performing a high volume of these procedures have found an incidence of 0.78% (21 of 285) of early femoral fracture requiring revision.\(^\text{13}\) Despite most stem types achieving reliable fixation, there are design features that may affect osseointegration. Cooper, Jacob and Rodriguez\(^\text{14}\) reported on a series of 320 THRs using a modern tapered stem, with a 4.7% rate of failure of osseointegration. The authors attributed this to a snug distal fit of a proximally...
coated, tapered stem, essentially preventing proximal infill.\textsuperscript{14}

**Technical aspects**
Modern tapered titanium stems accommodate very reproducible techniques of bone preparation. These flat, wedge-type designs require only a broach with no canal reaming. With the ability to start from a more medial entry point, and the lack of canal reaming, a flat, wedge–type stem is conducive to insertion through more limited exposures, such as the direct anterior approach.

**Other stem design features**
Other stem design features that may influence clinical outcomes are neck and trunion design variations. The head–neck ratio is important in affecting range of movement of the joint before impingement, so a higher head-neck ratio is desirable (Fig. 4). At the same time, this has to be balanced against the quality of the intersection of the head upon the trunion, so as to avoid fretting.\textsuperscript{15–17} In the future, refinements in trunion design will almost certainly play a key role in preventing corrosion at the head-neck junction, which is a potential source of adverse reaction to metal debris.\textsuperscript{15} Modular necks are a feature that has been introduced in an attempt to provide individual patient variation to the neck angle and off-set. However, early failures of these modular neck designs from corrosion at the stem–neck interface currently make this an unattractive stem feature.\textsuperscript{18–20}

**Conclusion**
Uncemented femoral fixation has become the method of choice for most THR surgeons in the USA. However, there are many design features that distinguish between the commercially available designs of cementless femoral stem. In the past 15 years, tapered titanium stems have rapidly out-paced extensively coated cobalt–chromium stems in terms of usage. The reasons for this include less thigh pain, especially in larger sizes, less stress shielding of the proximal bone, ease of insertion, versatility in their ability to accommodate various patient types, including those with osteopenic bone, obesity, or inflammatory arthritis. There are fewer complications of insertion and extraction with these types of stem. Modification of other features such as head-neck ratio and trunion design may further improve clinical results in the future.

**References**


