Large ceramic femoral heads offer several advantages that are potentially advantageous to patients undergoing both primary and revision total hip replacement. Many high-quality studies have demonstrated the benefit of large femoral heads in reducing post-operative instability. Ceramic femoral heads may also offer an advantage in reducing polyethylene wear that has been reported in vitro and is starting to become clinically apparent in mid-term clinical outcome studies. Additionally, the risk of taper corrosion at a ceramic femoral head–neck junction is clearly lower than when using a metal femoral head. With improvements in the material properties of both modern ceramic femoral heads and polyethylene acetabular liners that have reduced the risk of mechanical complications, large ceramic heads have gained popularity in recent years.

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Large ceramic heads (Fig. 1), referring to a head size of 36 mm or greater, are being used with increasing regularity in modern total hip replacement (THR). In a recent report describing THR component usage in the United States of America,\(^1\) the employment of ceramic-on-polyethylene bearing surfaces rose from 8% in 2007 to 19% in 2009. With new concerns surrounding the use of metal femoral heads in primary THR,\(^2\) this number is likely to grow. Less than 1% of all primary THR heads were larger than 32 mm in 2001, compared with 58% of all heads used in 2009.\(^1\) Manufacturers have recently produced even larger head options, with ceramic femoral heads currently available in sizes up to 48 mm.\(^3\) As these devices are being used with increasing frequency, it is important to understand their potential benefits and limitations.

Stability of large femoral heads
Instability remains one of the most common complications following primary and revision THR. Large heads reduce the risk of instability by providing greater range of movement (ROM), increasing the jump distance that the head must travel before dislocation occurs, and decreasing component impingement.\(^4\) Recent studies have provided excellent evidence on the effectiveness of large femoral heads in reducing post-operative stability following both primary and revision THR. In a retrospective study by Lombardi et al of 2020 primary THRs with heads > 36 mm, there was only one reported dislocation.\(^5\) Prospective randomised studies have also confirmed the benefits of large heads. Howie, Holubowycz and Middleton\(^6\) picked 644 patients at random to receive either a 28 mm or 36 mm femoral head. The risk of dislocation at one year was significantly greater for the 28 mm group (4.4%) compared with those with a 36 mm head (0.8%). In a randomised study of 184 patients undergoing revision THR to receive either a 32 mm (small) head or a 36 mm or 40 mm head and at a mean of five years post-surgery (two to seven), the large head group had a significantly lower incidence (\(p = 0.035\)) of dislocation (1.1%) when compared with those with a small head (8.7%).\(^7\)

Improved polyethylene wear
While larger femoral heads have been shown to have higher wear rates against conventional non cross-linked high density polyethylene than smaller heads,\(^8\) the effect seems to be minimal when heads are coupled with highly cross-linked polyethylene acetabular bearing surfaces.\(^9,10\) A recent clinical study\(^11\) of 102 hips at a minimum five-years follow-up (five to eight) demonstrated no difference in the linear wear rate and only slightly higher volumetric wear in patients with 36 mm and 40 mm heads.

In contrast, the wear associated with ceramic compared with metal femoral heads may be more beneficial in long-term clinical practice. In vitro wear simulator studies have demonstrated a clear advantage of ceramic...
over metal femoral heads in reducing both linear and volumetric wear, with the steady-state wear 40% to 50% less per given time for the ceramic heads.\textsuperscript{12,13} In vivo clinical studies have been less conclusive to date, however, the majority of studies focus mainly on older generation ceramic femoral heads, or provide only short-term follow-up with the newer ceramic and polyethylene components. Several studies on zirconia-on-polyethylene bearing surfaces, which are not commonly used today, demonstrate either no difference in the wear rates\textsuperscript{14,15} or only a small improvement.\textsuperscript{16}

Fourth generation ceramic materials, manufactured by inserting nano-sized yttria-stabilised tetragonal zirconia particles (Y-TZP) in a stable alumina matrix, were only introduced in 2004,\textsuperscript{17} and therefore long-term wear data is not yet available. However a recent study of such ceramic vs metal femoral heads on highly cross-linked polyethylene in 500 patients produced a significantly reduced linear wear rate (30% to 40% reduction) with the ceramic heads on radiographic measurements at early to mid-term follow-up (four to six years).\textsuperscript{18} As more data becomes available with longer follow-up, differences between metal and ceramic heads may become even more apparent.\textsuperscript{16}

Low risk of taper corrosion
The potential for corrosion at the modular head–neck junction of the femoral component was first described in the early 1980s.\textsuperscript{19} Although numerous subsequent studies raised concerns about fretting and corrosion at this junction,\textsuperscript{20–26} design and manufacturing improvements have resulted in universality of modular heads in modern THR. However recent reports have refocused attention on the potential adverse events that can occur as a result of metal debris secondary to corrosion at the femoral head–neck junction.\textsuperscript{27–30} Cooper et al reported ten patients who had undergone THR using a metal-on-polyethylene bearing surface, and presented with a painful adverse local tissue reaction at a mean of 3.2 years (0.7 to 8.7) post-surgery\textsuperscript{2}; additional cases were described in a subsequent report.\textsuperscript{31} All patients had elevated serum cobalt and chromium levels, and intra-operative findings demonstrated marked corrosion at the junction of the cobalt–chromium (CoCr) alloy femoral head with the neck. These patients had improvement in symptoms and returned to normal serum metal levels after revision to a ceramic femoral head.

Many protective advantages are conferred when the primary THR is performed with a modular ceramic femoral head. These femoral heads produce significantly less fretting\textsuperscript{32} and corrosion\textsuperscript{33} than those made of CoCr alloy, and therefore have a lower potential for metal release. Additionally, ceramic is an inert biomaterial, with no known biological reactions reported regarding ceramic wear debris. Ceramic heads are not completely protective against corrosion at the modular femoral head–neck junction, as several studies of retrieved implants have shown.\textsuperscript{33–35} However they are clearly more protective than CoCr alloy femoral heads in preventing complications secondary to corrosion.

Mechanical complications
Fracture of the ceramic head. Ceramic components in THR have always been associated with a small but finite risk of fracture due to their brittle nature,\textsuperscript{36,37} which has long been a cause for concern. Older ceramics had a low density and a very coarse microstructure that was not in compliance with modern design specifications. As manufacturing processes have evolved, the microstructure of the ceramic material has improved, providing greater fracture toughness. Willmann reported that fracture rates of ceramic femoral heads have decreased from 0.026% in first generation, 0.014% in the second generation, and 0.004% in third generation heads.\textsuperscript{38} While fourth generation heads (alumina
matrix composite) have been manufactured for less than a decade, their fracture rate is extremely low; a recent report of over 65 000 fourth generation heads reported no fractures after six years follow-up. The chemical composition of over 65 000 fourth generation heads reported no fracture, torsion after six years follow-up. The chemical composition of over 65 000 fourth generation heads reported no fracture, torsion after six years follow-up.

Conclusions
Large ceramic heads offer the potential to improve long-term wear performance and produce a lower risk of postoperative instability, which address two of the most common forms of failure confronting patients undergoing primary THR. When used with a titanium stem, ceramic heads also eliminate the potential for Co and Cr ion release into local soft tissues from trunnion corrosion, therefore reducing the possibility for adverse local tissue reactions. Improvement of materials has significantly lowered the risk of femoral head or acetabular liner fracture, and results in safe use of larger ceramic heads. Thus, we routinely use ceramic-on-polyethylene as the bearing of choice in the majority of our patients undergoing THR.

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References